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REPORT OF THE JOINT BOARD

UPON THE

RESTORATION OF GREEN HARBOR

1898

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REPORT OF THE JOINT BOARD

CONSISTING OF THE

HARBOR AND LAND COMMISSIONERS AND THE STATE BOARD OF HEALTH,

UPON THE

RESTORATION OF GREEN HARBOR

IN THE

TOWN OF MARSHFIELD, MASS.

CHAP. 495, ACTS OF 1896; CHAP. 98, RESOLVES OF 1897.

JANUARY, 1898.

BOSTON:
WRIGHT & POTTER PRINTING CO., STATE PRINTERS,
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1898.

Acts of 1896, Chapter 495.

AN ACT RELATIVE TO THE RESTORATION OF GREEN HARBOR IN THE TOWN OF MARSHFIELD.

Be it enacted, etc., as follows:

SECTION 1. The board of harbor and land commissioners and the state board of health, acting as a joint board, are hereby required to cause an examination of Green Harbor in the town of Marshfield, and of the Green Harbor marshes and the dam and dike constructed across Green Harbor river under the provisions of chapter three hundred and three of the acts of the year eighteen hundred and seventy-one, to be made by competent engineers, who shall report to said joint board the result of their examination; and if upon receiving such report said joint board shall determine that a substantial improvement in and benefit to Green Harbor will result from the removal of said dam and dike, and that no damage to vested property rights greater than the benefit and improvement to be derived from such removal will result therefrom, then the board of harbor and land commissioners shall remove said dam and dike, and shall replace such portion of the highway as may be destroyed by such removal, by a suitable bridge, either with or without a draw, as said board of harbor and land commissioners may determine that public convenience requires. The joint board and the board of harbor and land commissioners shall make a full report of their doings under this act to the general court at the next session thereof.

SECTION 2. Any person who suffers injury to any vested property right by reason of the removal of said dam and dike shall be entitled to have his damages assessed against the Commonwealth by the county commissioners of the county of Plymouth, with like right of appeal as in the case of land taken for the construction of highways: *provided*, that in case the Commonwealth shall be liable for damages to property, the increase in value, if any, which has accrued by the building of said dam and dike under the provisions of chapter three hundred and three of the acts of the year eighteen hundred and seventy-one, shall be deducted in the assessment.

SECTION 3. To defray the expense incurred under this act a sum not exceeding twelve thousand dollars is hereby appropriated, to be paid out of the treasury of the Commonwealth from the ordinary revenue, subject to the approval of the board or boards incurring the expense.

SECTION 4. If the board of harbor and land commissioners shall remove said dam and dike, then so much of chapter three hundred and three of the acts of the year eighteen hundred and seventy-one as authorizes the construction and maintenance of a dam and dike across Green Harbor river in the town of Marshfield shall, from the date when said removal is commenced, be repealed. [*Approved June 5, 1896.*

Resolves of 1897, Chapter 98.

RESOLVE EXTENDING THE TIME FOR THE REPORT OF THE JOINT BOARD OF HARBOR AND LAND COMMISSIONERS AND STATE BOARD OF HEALTH ON THE RESTORATION OF GREEN HARBOR IN THE TOWN OF MARSHFIELD.

Resolved, That the time in which the joint board of harbor and land commissioners and the state board of health shall report on the restoration of Green Harbor in the town of Marshfield, under the provisions of chapter four hundred and ninety-five of the acts of the year eighteen hundred and ninety-six, be extended to the first Wednesday in January in the year eighteen hundred and ninety-eight; and that said board be authorized to report in print, with plans. [*Approved June 11, 1897.*

REPORT OF THE JOINT BOARD UPON THE RESTORATION OF GREEN HARBOR IN THE TOWN OF MARSHFIELD.

To the Honorable the Senate and House of Representatives of the Commonwealth in General Court assembled.

In accordance with the provisions of chapter 495 of the Acts of 1896, the Board of Harbor and Land Commissioners and the State Board of Health met on July 15, 1896, for the purpose of organization as a Joint Board. Henry P. Walcott was elected chairman, Frederick N. Wales was appointed secretary, and Frank W. Hodgdon, C.E., and X. H. Goodnough, C.E., were directed to make an examination of Green Harbor and of the Green Harbor marshes and the dam and dike constructed across Green Harbor River, and to report to the Joint Board the result of their examination.

The Joint Board has personally inspected the localities concerned, has held a public hearing at Green Harbor, has caused experiments to be made in order to discover the probable results of again subjecting the marshes above the dike to the direct influence of the waters of the ocean, and has gathered all the facts available which show the influence of the existing conditions upon the health of the neighborhood.

The engineers of the Board proceeded at once to undertake the examinations called for in chapter 495 of the Acts of 1896. They prosecuted their inquiries with commendable diligence, and have presented to the Joint Board their final reports, which will be found in Appendix No. 1. After careful consideration of the reports, it was unanimously voted, on Dec. 9, 1897, "That, in the judgment of this Joint Board, the Green Harbor dike, so called, should not be removed, and that a report to the General Court be made upon the basis of this judgment and vote."

The reasons which led the Joint Board to this conclusion are contained in the following pages.

The Board was directed by the above-mentioned act to settle two questions; first, whether a substantial improvement in and benefit to Green Harbor would result from the removal of said dam and dike; and, second, whether the damage to vested property rights would be greater than the benefit and improvement to be derived from such removal.

The small village of Green Harbor is situated in the southeasterly portion of the town of Marshfield, at the mouth of the Green Harbor River. The permanent population of the region lying about Green Harbor is not large, — probably less than 200, — but the attractions of the place are sufficient to bring here in summer nearly 2,500 temporary residents. Marshfield itself had, by the State census of 1895, a population of 1,760. In 1840 it had a population of 1,761.

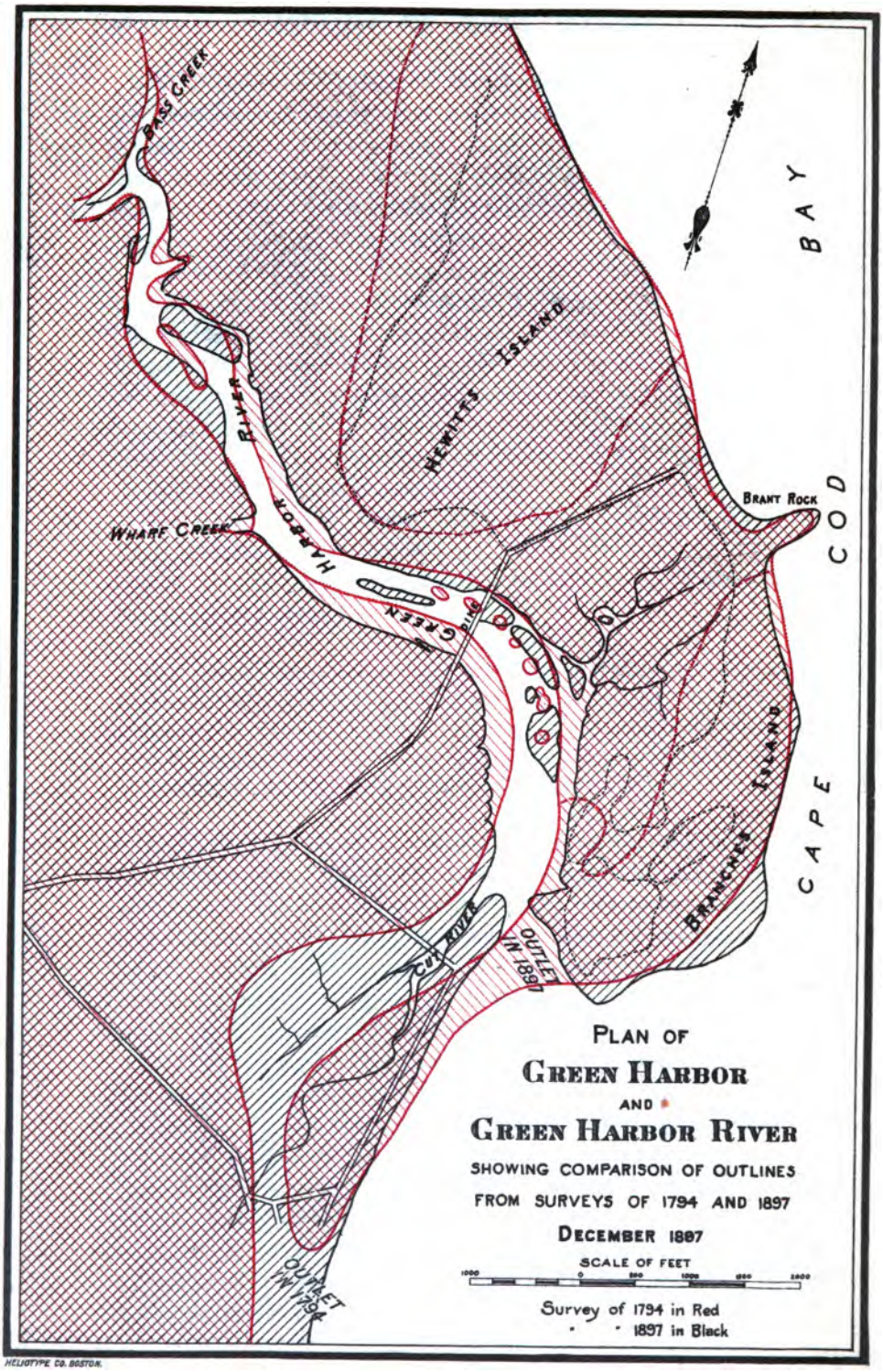
The region about Green Harbor was occupied by settlers from Plymouth soon after the establishment of the Colony, and in the Court Records, under date of July 1, 1633, appears the following entry: —

> That unless Mr. Gilson, John Shaw and the rest that undertooke the cutting of the passage between Green's Harbour and the bay, finish it before the first of October next ensuing, according to covenant, they be amerced in ten pounds; but if any of them will doe it, the fine be exacted of the rest, and they paid for their labour.

Early in 1636 there is another order of the court, that the cut at Green's Harbor for a boat passage be made 18 feet wide and 6 feet deep, and the governor, with certain assistants, was authorized to direct the work. The cut referred to in these extracts is evidently a channel cut to enable boats to pass from Plymouth harbor to Green Harbor River, and thereby avoid going outside the Gurnet.

In 1785 a petition was presented to the General Court asking for an act to prevent the use of Marshfield beach for grazing purposes. No act was granted at this time, but in connection with this petition a copy of a will was presented, in which the marsh lands in the vicinity of Bass Creek a tributary of the Green Harbor River, entering it about a mile above the dike, are referred to as "salt marshes." No further reference that is of interest in connection with Green Harbor is found in the Colonial Records.

PLAN NO. 1.



HELIOTYPE CO. BOSTON.

Upon the map of Marshfield made in 1794, on file in the department of the Secretary of the Commonwealth, the mouth of Green Harbor River is shown to be about five-eighths of a mile south of its present outlet. A copy of this map, showing the mouth of the river as it existed in 1794, and a copy of the map of 1897 are shown opposite.

The first mention of Green Harbor that is of interest in the Acts and Resolves of the State is in 1807, when an act was passed to establish a corporation for the purpose of draining Green's Harbour marsh, so called, in the town of Marshfield. The petition for this act appears to have been presented to the House of Representatives on May 29, 1806, and is as follows: —

To the Honorable the Senate and House of Representatives of the Commonwealth of Massachusetts, in General Court assembled —

The subscribers, owners and occupants of certain meadows, lying in the town of Marshfield in the county of Plymouth humbly represent, that whereas a certain River, called Green's Harbour River in said town of Marshfield has in times passed afforded an outlet to the waters, which have overflowed about two thousand acres of said marsh, and whereas lately the mouth of said River has been closed, by beach sand, confining a great body of water on said marsh, which may prove entirely destructive of said meadows and it has become absolutely necessary that said water should be drawn of in the most convenient manner possible, and Whereas, we the subscribers, owners and occupants of the marsh aforesaid, for the preservation of the same, have associated for the purpose of draining said waters from said marsh into Duxboro Bay, by digging a canal for said water and having in said enterprise expended about the sum of three thousand dollars for the purpose aforesaid, pray the Honorable Court that we and our associates may be incorporated into a Body Politic, to manage the above undertaking and be possessed of all the powers and privileges, usually granted to similar incorporations and as in duty bound will ever pray — (Signed) Isaac Winslow, and others.

In response to this petition, chapter 39 of the Acts of 1807 was passed, on Feb. 11, 1807, incorporating the Green's Harbour Canal Company for the purpose of draining Green's Harbor marsh in the town of Marshfield. Section 1 of this act is as follows: —

Be it enacted by the Senate and House of Representatives in General Court assembled, and by the authority of the same, That Isaac Wins-

low, Luke Wadsworth, Judah Thomas and Benjamin White, proprietors in Green's Harbour Marsh in the town of Marshfield, together with their associates, and such others as may hereafter associate with them and their heirs and successors, shall be a Corporation by the name of Green's Harbour Canal Company, with all the powers and privileges incident to similar Corporations, for the purpose of draining the stagnant water of Green's Harbour Marsh in the town of Marshfield and for better improving said Marsh, by erecting dikes or removing bars of sand, rocks or other obstructions that oppose the draining of said marsh, for digging a canal or canals for said water to pass into Duxbury or Plymouth Bay, and building a bridge or bridges across said canal or canals, if the same should intersect any private or public highway, and by the name aforesaid, may sue or be sued, and do and suffer, whatever other similar Bodies Politic may or ought to do and suffer.

In 1812 another petition was presented to the Legislature by the Green's Harbour Canal Company, relative to the preservation of Marshfield beach, which had been the subject of legislative consideration in 1785. The petition of the Green's Harbour Canal Company is dated May 23, 1812, and is as follows: —

To the Honorable Senate and the Honorable House of Representatives of the Comonwealth of Massachusetts in General Court assembled.

The petition of the Green's Harbour Canal Company in the County of Plymouth — Humbly shews, — that the said Company are Proprietors of a certain Tract of salt Marsh-land, lying in the town of Marshfield in said County of Plymouth — that said Marsh is defended from the Sea, on the Northeast, by a Beach called Marshfield Beach — that Anno Domini 1806 the River called Green's Harbour River, which runs thro' said Marsh and Beach into the Sea, was filled up with Sand, by a violent Storm which caused the whole Marsh, together with the low Land contiguous thereto, to become a Lake, by estimation, of about 2000 acres of stagnant Water — that, on this emergence your Petitioners were obliged to open a Canal into Duxbury Bay and build a bridge over the same; which cost them nearly 2000 Dollars — the Canal answered a good Purpose for draining the Marsh; but did not admit sea water enough into the Marsh, to preserve it, in its former State; some Parts thereof producing Rank Weeds of various kinds, and other Parts Nothing at all — Anno Domini 1811, another violent Storm forced a new Channel or River thro' said Beach, at a considerable distance from where the former River was filled up, and said Channel now remains, sufficient

it is said, at full Tide, for a Vessel of 100 Tons to enter — that there are now some Places in the Beach, the whole length thereof being about 5 Miles, so low that the tides, when in a Course to be high, flows across them into the Marsh — That there often are Cattle ranging up and down the Beach and Horses turned out to graze thereon, by Gunners and Fishermen who resort there; by which means not only the Tops of the Grass are taken of; but the Roots so started and the Sand so loosened that the Wind has more Power to level the Beach — That there has been some Labour taken to hedge the Beach with Brush, which has been found ineffectual, the Cattle frequently levelling it with their Horns, out of mere Frolic — That the damage to said Company on account of the Loss of the Produce of said Marsh, has been equal if not greater than the cost of opening the Canal — That it is a Public Damage is certain, especially to the back Towns in the Vicinity, as they were usually relieved, in some measure, by our Salt Hay, when their English was cut short by Drought etc., — That the Whole number of the said Proprietors is about 120, and that about one half of them do not reside in Marshfield, for which Reason it was thought most proper for the Proprietors to Petition, and not the Town — That said Company do not wish to deprive any Individual or Individuals of any legal right they have in said Beach, without an adiquate compensation therefor — For the foregoing reasons, and some others that might be offered, your Petitioners humbly pray that this Honorable Legislature would be pleased to take their embarassed situation into serious consideration, and grant them relief by some special Law or Act, as in their Wisdom they may judge best for the Preservation of said Beach, it being, as they are told, the only Beach in the Vicinity, if not in the State that is destitute of a special Law to preserve it — So shall ever pray as in Duty bound

Marshfield, May 27, 1812. (Signed) LUKE WADSWORTH,
Agent of Green's Harbour Canal Company.

The petitioners were given leave to withdraw, and nothing more with reference to Green Harbor appears until June, 1826, when a petition of the inhabitants of the town of Marshfield was presented to the Legislature as follows: —

To the Honorable Senate and House of Representatives of the Commonwealth of Massachusetts, in General Court assembled, June A.D., 1826.

The petition of the inhabitants of the town of Marshfield in the County of Plymouth — Humbly showing — that said town is bounded easterly about 5 miles by the Sea or Bay of Massachusetts, between Duxbury and Scituate — that there is two valuable tracts of salt Marsh

or Meadow, containing between 2,000 and 3,000 acres, together with a considerable quantity of low land contiguous thereto; all of which is defended from the sea, by a beach and two islands; the one called Hewett's and the other Branches Island — that, of late years, the said beach has been in a shifting and uncertain state — that, at one time the mouth of the River, called Green's Harbour River, that runs through the marsh and beach into the sea, is choked or stopped up, by a bar of sand, and the meadow becomes a lake — that, at another time, the flood breaks or bursts through the beach, and opens a new channel or river in a place where there was never one before, since the memory of man — that the mouth of said River is now so wide that it admits, or lets in, so much tide, that it is difficult to make the hay on the meadow — And that, in the winter before last past, there was so much tide forced through the mouth of the river and over the beach at other places, in the time of a storm, that the greatest part of the stacks of hay, were taken off the stadles and carried on the upland and into the swamps adjacent — And as it is the general practice in this Commonwealth, to make application to the General Court for a special act or law to preserve and secure from damage beaches like circumstanced with ours, we therefore humbly pray this Honorable Court, to grant us an act or law to preserve and secure from damage the whole of Marshfield Beach, excepting the seashore lying directly between the aforesaid Islands and the Sea; and that said law relative to Marshfield Beach may be, in general, similar to the law granted to the inhabitants of Duxbury, relative to Salter's Beach, A.D. 1808; in particular as it respects the prohibition of grazing that beach. —

So, as in duty bound, shall ever pray, the Inhabitants of Marshfield — (Signed) Luke Wadsworth, *Agent.*

A remonstrance was presented to the General Court in January, 1827, which is of interest in this connection, and is as follows: —

To the Honorable the Senate and House of Representatives of the Commonwealth of Massachusetts in General Court assembled.

The subscribers inhabitants of the town of Marshfield in the county of Plymouth ask leave respectfully to remonstrate against the petition of Luke Wadsworth agent for said town, now pending before your Honorable Body, to the extent and for the reasons here assigned.

The necessity and propriety of having something done for the preservation of a part of Marshfield Beach is admitted. But about one half of said beach is flanked on the inside by elevated and rocky

upland; and most of the residue has, ever since the memory of man, 'till within a few years, been preserved by means of a hedge erected and maintained thereon by the adjacent meadow owners; and the experience of more than 100 years has tested and established the efficacy and economy of this mode of security. For the past 10 or 15 years, however, the hedge has been entirely neglected and during that period, the encroachments of the sea on the beach have been constant and perceptible. But although cattle have been permitted time out of mind to graze thereon, until the neglect of the hedge as aforesaid, no alarming or dangerous inroads were ever made by the sea. And in April last the gaps in said beach laying between Major Thomas' farm and Hewett's Island about one mile in length amounted in extent to about 80 rods and were hedged at an expense of about $30 or $40, and the effect of one season thereon has demonstrated anew the entire efficacy and economy of this mode of defence.

The herbage of said beach is valuable. Portions thereof are, as we are informed, claimed as the fee simple estate of the adjacent upland owners, and the right of feeding the whole thereof is claimed by different individuals as their right. If then cattle are excluded therefrom, we apprehend the town would be unavoidably involved in much and expensive litigation; and if ultimately compelled to make good all injury to individuals, we see not how the town can escape from the payment of heavy damages.

Under these circumstances we do most respectfully remonstrate against the passage of an act to exclude cattle from said beach as altogether unnecessary and inexpedient, because another and much cheaper mode of defence may be adopted, which experience has shown to be effectual.

And as in duty bound will ever pray, (Signed) JOSEPH CLIFT, Jr.
JOTHAM TILDEN and others.

An act was passed Feb. 21, 1827, being chapter LXXXI. of the Acts of that year, giving the inhabitants of the town of Marshfield authority to build a sea-wall, palisades or hedge fences to preserve and secure the whole of Marshfield Beach from incursions and encroachments of the sea, excepting the seashore lying directly between Hewett's and Branch's islands and the sea, and granting authority also to keep the same in repair. Another section of the act provided that no cattle, horses, sheep, etc., should be admitted to go at large on the beach.

On Dec. 14, 1829, the Green's Harbor Canal Company petitioned to be dissolved, stating that the purposes for which the said corporation was created had been effected so far as the

same were practicable, and that their continuance as a corporate body was useless, and productive only of unnecessary trouble and expense. A remonstrance was received from the town of Duxbury, setting forth the value of the canal into Duxbury Bay for their use in transporting timber, hay and other materials; but an act was passed March 16, 1831, dissolving the Green's Harbor Canal Company.

A map of the town of Marshfield, dated 1831, and on file in the archives of the Secretary of the Commonwealth, shows the mouth of the river at approximately the same location as it is found to-day, but this map gives no details of importance.

The evidence is conclusive that the mouth of the river was in 1794 about five-eighths of a mile south of its present location; and the statements made by petitioners and not denied by remonstrants indicate that this outlet was closed by sand not long previous to May, 1806, when the petition was presented to the Legislature for the incorporation of the Green's Harbor Canal Company. No information is furnished, however, as to the depth of the mouth of the river, but it is stated in a note that its width just above its mouth was about 8 rods, though it widened quickly inside to 60 rods. Another note upon the plan of 1794 states that it was full sea at a point a short distance below Green Harbor bridge near the upper end of the marsh about two hours later than at the sea-shore, indicating that the tide was retarded considerably in its flow up the stream, which was probably principally due to obstruction at the outlet, though it may have been due to obstruction further up stream. It appears from the petition for the incorporation of the Green's Harbor Canal Company that the mouth of the river was closed by sand during a violent storm a short time previous to May, 1806, and that for a period of four or five years succeeding this time the mouth of the river remained closed; but from a petition of the Green's Harbor Canal Company in 1812 and from other information it appears that a new channel was opened by the sea in the latter part of 1810 or early in 1811, and that the new channel was approximately at the place where the mouth of the river is found at present. This channel was said to be in 1812 sufficient, at full tide, for a vessel of 100 tons to enter. Tradition seems to indicate that this channel was begun artificially. The next recorded state-

ment as to the condition of the river is found in the petition of June, 1826, quoted above, alleging that the mouth of the Green Harbor River had of late years been in a shifting and uncertain state, being at one time choked by a sand-bar and at another time being open freely. The petition of the Green's Harbor Canal Company for dissolution in 1829 states that the drainage of the marshes, for which purpose the company had been incorporated, had been effected as far as practicable. The map of Marshfield, dated 1831, as already stated, shows the mouth of the river at about the same location as it is found to-day, but gives no details of importance.

The next information found relative to this harbor is the work of the United States Coast Survey. Soundings were taken along the coast in this region in the years 1854 and 1855, and the first complete topographical map of the coast was made in 1857; copies of the plans of these surveys have been obtained from that department. The sheet showing the soundings is plotted to a scale of 1 in 80,000, or about 6,667 feet to an inch, and only two or three soundings are shown in the vicinity of the mouth of the river. One of these soundings, located at the outer end of the present channel, showed a depth of 1 foot at low water. The chart of this coast, based on this survey, shows a depth of 1 foot at low water at the outer end of the harbor. The topographical survey was plotted on a scale of 1 in 10,000, or 833⅓ feet to an inch, and shows the mouth of the harbor substantially in its present position. The high and low water lines of the harbor are shown from its outlet for a long distance up through the marshes, but no soundings are given, and it does not appear that any were made.

In 1870, when the question of reclaiming the marshes was under consideration, examinations, surveys and some tidal and current measurements were made under the direction of the United States Coast Survey by Assistants Henry Mitchell and H. L. Whiting; but it does not appear that any soundings of the harbor or any surveys of its contour were made at this time. The only records of this work which were found are contained in the report of the United States Coast Survey for 1869; and it is stated by the superintendent, in reply to a request for additional information, that nothing further is on file in the office of the survey than the report referred to.

Extracts from this report are published in the fifth report of the Harbor Commissioners, dated January, 1871, and from this report the following extract of a statement by Professor Mitchell with regard to the harbor is taken: —

> The lower reach of the river is known as Green Harbor, whose length from Turkey Point to the bay is about $\frac{7}{8}$ of a mile and whose maximum low water width scarcely exceeds 500 feet. A sand bar obstructs the entrance, upon which there is from 2 to 3 feet of water at ordinary low tide, the average rise being 9 feet, and vessels can take the ground within the harbor at low tide without injury.

In the report of Professor Whiting is found the following statement: —

> As a small local harbor it also has some character. Once within the mouth of the river, a small vessel would find good anchorage, sufficient depth of water and complete shelter. The entrance, however, is shoaler than the river within, and really cannot be called navigable at low water.

The dike was completed in the year 1872, at a cost of $32,090.79, and subsequently in 1879 was widened to carry the road from Green Harbor to Brant Rock.

The Acts of 1871 authorized the construction of a dam and dike across Green Harbor River for the purpose of "improving the Green Harbor marsh in the town of Marshfield and for other purposes." Following the building of the dam and dike came certain changes in the small harbor at the mouth of the river. The effect of these changes was a serious one for the fishermen of the village, and in the course of years much feeling has arisen between the parties in the town, composed respectively of those in favor of the dike and of those opposed to it and in favor of its removal.

In view of the directions of the Legislature to deal with a condition of things which we find to be now in existence, it is fortunately unnecessary for us to rehearse the long story of this the most stirring episode in the history of this peaceful New England village.

It is undoubtedly true that this small harbor has deteriorated since the building of the dike, and we believe that the dike is responsible for a portion of the mischief done; but, as will be

seen by the brief statement of the history of this river, it is not clear that the harbor has been at any time safe from a calamity similar to that which befell it in the earlier years of the century. That such catastrophes in harbors of this character are not uncommon may be learned from the history of the North River, only a few miles distant from this place.

The changes which have taken place in Green Harbor may be seen on Plan No. 3.

The changes which have taken place over the meadows above the dike are fully as important as any which have been observed in the harbor, and might easily become a source of danger to the communities around the harbor of far greater moment than the shoaling of the waterways.

The Green Harbor marshes, like all others of the same composition, shrink rapidly when drained, and this shrinkage has a tendency to continue until the surface approaches the permanent water level, and obtains a consistence dense enough to resemble the conditions of ordinary cultivable soil. The amount of subsidence depends mainly upon the more or less spongy character of the marsh.

When the salt water of the soil is replaced by fresh water, the larger portion of the vegetation peculiar to salt marshes disappears, the roots decay after the lowering of the water level, still further increasing the shrinkage, and then come the grasses and plants adapted to fresh-water areas.

All the evidence in our possession shows that this subsidence has taken place all over the marshes located above the dike, ranging in amount from a few inches to several feet. The map shows the present elevations of the surface of the meadow, and from a careful examination of this it appears that an area of 1,334.3 acres, excluding water surfaces, would be covered by every mean high tide in case the dike should be removed.

The first effect of such applications of salt water to this surface would be the prompt destruction and decay of the fresh-water vegetation now established here, and then would come a period of uncertain duration, when there would be little or no vegetation, but only an expanse of unsavory mud flats, emitting foul odors.

It might then be possible that the thriving settlement along the Marshfield beach to the east of this great expanse of mud

flats, and exposed to all the smell brought over by the western breezes, would have some reason to complain that the Commonwealth had not equally guarded all the varied interests of this community.

The removal of the dike would not by any means restore a condition of things existing before the construction of this barrier. An amount of water far in excess of anything before known would tear through the light sands which form the margins of the harbor, and produce effects which cannot easily be measured, but which we have every reason to suppose would be disastrous.

It will be observed that a number of houses have been built on land formed since the dike was built in the vicinity of the northerly end of Duxbury Beach. We have every reason to suppose that this sand bank could not withstand the eroding action of currents far stronger than any that existed in the days when a smaller volume of water prevented this encroachment on the waterways.

For the purpose of ascertaining the conditions of healthfulness in this district, we have caused tables to be prepared, showing the causes of deaths and the death rates for a period of thirty years; but we cannot discover in these tables satisfactory evidence of the existence of conditions prejudicial to health. The average death rate for the whole period has been 17 per 1,000, which is below the general death rate of the State for the same period. The well-founded belief of the people in the present health-giving qualities of this region is shown by the steady increase in summer visitors and by the many houses built in the immediate vicinity of the harbor and river.

The builders of the dike were sanguine in their expressions of belief in the value of the reclaimed marshes for agricultural purposes; but we find many residents of Green Harbor who have serious doubts as to the real value of these fields. We were fortunately able to draw to our assistance Edmund Hersey, Esq., of Hingham, whose wide experience and ample knowledge in the science and art of agriculture have made him a much valued authority in this department.

From his report we make the following extracts: —

In my investigation of the Marshfield dike meadow, to estimate its value for agricultural purposes, it seems to me to be necessary to

ascertain, as near as possible, what has been produced on that portion which has been under cultivation the greatest number of years since the dam was built.

Fortunately, for this information I do not have to depend on interested parties nor the statements of enthusiastic men. Soon after the dam was built, I was employed as editor of a prominent agricultural paper of New England. In this position, it became my duty to thoroughly investigate every new enterprise which related to agriculture; and the Green Harbor dike meadows received a watchful attention.

I have visited the premises many times while the crops were being harvested, and at other seasons of the year. When I consider the discouraging circumstances under which the owners of this land have had to work, I am surprised at the great success which has attended their labors.

As early as 1878, six years after the dam was built, Dr. C. A. Goessmann, State chemist, in a report on salt marshes, referring to this meadow, stated that: "The present unsettled legal aspect of the matter cannot do otherwise than exert an unfavorable influence on the adoption of a more thorough system of improvements, and thus retard the progress in the cultivation of the reclaimed lands."

In a report made in the year 1879 on the improvement of salt marshes in the town of Marshfield, referring to the dike meadow land at Green Harbor, he again remarks: "Many people doubted in the outset the general adaptation of the reclaimed sea-marshes for the production of English grass without previous application of top-dressing of some kind or other; yet time has proved otherwise. Those who have seen the grass on these meadows during the past season, or witnessed the carting away of the many loads of good English hay, have had all doubts regarding their productiveness, under even moderate chances, removed. The results thus far obtained have been more than many of the friends of the enterprise anticipated; and have convinced even the most skeptical, who are open to conviction, of the exceeding natural richness of the soil, and its excellent adaptation for the cultivation of a variety of crops. Still greater results will be secured, no doubt, in future, providing the improvements are allowed to be developed unchecked by adverse judicial decisions."

In the year 1880 Dr. Goessmann reports: "We believe the community never had more confidence in the richness and the fertility of the soil than they have to-day. The proprietors, as a rule, have never had more faith in the results of the enterprise, so far as remunerative crops are concerned, than now. Evidently nothing but a favorable final decision in the courts is needed to secure outside capital for

more general and rapid development of the agricultural resources of the reclaimed sea-marshes at Marshfield, Plymouth County, Mass."

These reports of Dr. Goessmann were made to the Massachusetts Board of Agriculture, and may be found in the secretary's reports for the years 1878, 1879 and 1880.

. . . . . .

While visiting the Marshfield meadows on April 19, 1897, I found asparagus already up, very nearly high enough to cut. I was surprised at this, because my own asparagus had but just appeared above the surface of the ground, although growing on land so warm that I am usually the first to ship native asparagus to Boston market. I was also surprised at the size of the stalks, they being much larger than the first set of stalks which appear on my land. When I consider the fact that the land on which this asparagus was growing has produced large crops every year for twenty years, without fertilizers of any kind, and still produces better crops than my land, which has had six hundred dollars' worth of fertilizers to the acre applied to it during the last twenty years, it convinces me that this land, for garden purposes, surpasses any which I have ever examined.

I noticed on the meadow, strawberry plants which had passed through the winter uninjured, and were looking well; thus indicating that the strawberry will grow well on this land, after the top soil becomes well decomposed.

On the 3d of July, the meadows were visited to examine the hay which was then being harvested; it not being a good hay day, a very large proportion of the hay was raked in heaps, thus affording an excellent opportunity to judge of the amount produced on various parts of the meadow. While some portions of the land on which the hay was raked into heaps would, in my opinion, not produce quite two tons to the acre, a considerable portion of it would, I have no doubt, produce more than two tons to the acre, and some of it at least two and one-half tons per acre; and I think I may be safe in saying that the average would be two tons per acre.

A number of years ago, while visiting these meadows, I saw one field of seventy acres that was being harvested; some of it was spread over the ground as left by the mower, but most of it was raked in windrows and heaps ready to be loaded on wagons. This, I estimated, would produce an average of two tons to the acre. I was subsequently informed that the seventy acres produced one hundred and fifty tons.

When we consider that this was produced on land that had never had its natural richness increased by the application of any fertilizers, we realize, in a measure, the great value of the material which nature has for ages been storing up for man's future use, if he be wise enough to avail himself of it.

As some persons have expressed doubts as to the good qualities of this hay, and others have stated that neither cows nor horses will eat it, I purchased some of the last season's growth, to test it by the side of hay grown on my own farm, my horses to be the judges. My hay was what I have been selling for first quality, composed of redtop and timothy. The test was made in this way: I took about a half pound of the Marshfield hay in one hand, and the same quantity of my hay in the other, holding each bundle so that they would be of equal distance from the mouth of the horse; he first took a small quantity of my hay, but immediately turned to the Marshfield hay, and took from it a mouthful; and after this, although I put my hay in front of it, he would, every time, smell of mine, and then reach over and take a mouthful of the Marshfield hay; this he followed until he had eaten all of the Marshfield hay.

I then led out the second horse, and tried him in the same way, and he went through the same actions that the first horse did, which afforded much amusement to those who witnessed the performance. The next day another trial was made, with the best hay I could select from my barn; two small bundles, one of mine, and the other of the Marshfield hay, were held in one hand; and, although the bundle of my hay was held next to the horse, after taking one small mouthful from my hay, he reached over and began to eat of the Marshfield hay, and continued to do so until he had eaten it all. I confess I did not expect this, because I consider my hay to be of excellent quality, — I thought as good as the best. My horses have decided the case against me.

While visiting the meadows on September 22, I examined the crops of cranberries, Indian corn and onions.

Several cranberry bogs were visited, from which the fruit was being gathered. The present year not being as favorable as last year for the growth of this fruit, I did not find the crop so large. One of the growers estimated that he should get one hundred barrels per acre; but in my judgment, formed after forty years' experience in the business, I should say seventy-five barrels would be nearer right; but, even if there be only fifty barrels to the acre, this would secure a net profit of one hundred and fifty dollars to the acre, if sold at a price which I am selling my berries for to-day. The lower levels of this land, if not high enough to be readily drained for small fruits, grain and vegetables, I have not a doubt can be very profitably used for the growth of the cranberry.

The season being unfavorable, the corn crop was not large; but from what I saw I should think it would yield fifty bushels to the acre.

The onions were rather above an average crop grown by market gardeners who use large quantities of fertilizer. Both of these crops

were grown without the application of any kind of fertilizer, and on land that for more than twenty years has produced large crops of hay, grain and vegetables; and yet, to all appearances, the soil is in the best condition for the production of large crops of small fruits and garden vegetables.

The several close examinations which at different times I have made of that part of the meadow which has been thoroughly drained and cropped from ten to twenty years or more, led to the belief that the mechanical condition of the soil is better adapted to the growth of garden fruits and vegetables than any land I have ever examined; and that it retains its richness to a wonderful degree, is proved by recent analysis of the soil, as well as by the large crops it produces without the aid of fertilizers.

. . . . . .

An examination of the dam shows that, when an effort was made to destroy it, the injury was such that it has never been made tight, but at every tide a large quantity of sea-water finds its way through the injured part. It is evident to me that, if the owners of the land could be assured that the dam would be permitted to remain unmolested by legal tribunals and individuals who pay no respect to law, it would be but a short time before the sea-water would be shut out, and the whole meadow drained in a systematic way. When this is done, it would be but a short time before not only the salt from the surface of the lowest levels would be washed out, but the subsoil of the whole meadow would be freshened sufficient to increase the large crops which are now grown on the improved portions, and the whole territory so improved that it would produce as large crops as the best of it now produces. This being evident, justice demands that my estimate of the agricultural value of this land should be based on what would be its condition if the dam had been uninjured, and the owners had possessed full confidence that whatever improvements they might make would not be interfered with, either legally or illegally.

The careless observer, who knows nothing of the history of the opposition and the discouragements which the owners of this land have met with in their efforts to make improvements, might, and undoubtedly would, come to the conclusion that the portion of the meadow which has not been improved is of but little value; but those who thoroughly investigate the whole subject, and make themselves familiar with its complete history, fully realize that the whole territory can be easily changed to a condition to insure large crops of small fruits, garden vegetables or the best quality of hay; and, what is most surprising to those who grow these crops on higher levels, they have been grown, and will continue to be grown, without fertilizers.

If I am to estimate the true value of this land, I am quite sure that I must consider the fact that for twenty or more years it has produced large crops without the application of manure or fertilizers of any kind, and that the soil shows no evidence of losing its fertility for many years yet to come; although to do so I am aware that it will bring its value up to a sum that will seem unreasonable to those who do not give the subject careful, intelligent thought, or who have not had experience in buying large quantities of fertilizers to keep up the fertility of a market-gardener's farm.

My own experience teaches me that it will require the application, every year, of at least ten dollars' worth of fertilizers to each acre, on what we consider good grass land, to secure as large crops as are secured every year on this land without fertilizers; and to secure as good corn, at least thirty dollars' worth of fertilizers must be applied to each acre of land which we consider good corn land; and to produce such garden vegetables and strawberries as are grown on this land without fertilizers, few market gardeners apply less than fifty dollars' worth of fertilizers to each acre.

Other things being equal, the real value of this land for grass would be a sum which, if placed at interest, would secure a net income each year of ten dollars; add to the sum thus required the value of what is considered to be the fair value of an acre of good grass land, say forty dollars, and we shall get at what it seems to me is the true value of this land for the production of hay; for the production of Indian corn, the sum to be considered must produce an annual income of thirty dollars, and for garden vegetables fifty dollars. It is fair to presume that, when the owners of this land are assured that the dam will remain unmolested, and the water shut out, it will be but a few years before this land will be too valuable for the production of hay, and will be used for the production of small fruits and garden vegetables. I say this notwithstanding I have the evidence that one measured acre has produced 6,800 pounds of hay in a season, and another acre 34 bushels of rye and 5,454 pounds of straw.

The lower levels of the meadow are admirably adapted to the growth of the cranberry; so well that when grown by those who understand the business it will pay quite as well as any other crop which can be grown on the higher levels; thus the whole 1,400 acres can be utilized for various crops at a large profit.

The act under consideration requires the Board of Harbor and Land Commissioners to remove the dam and dike, in case the Joint Board shall determine that a substantial improvement and benefit to Green Harbor will result therefrom, and that no damage to vested property rights greater than the benefit and improvement from such removal will accrue therefrom.

We are thus led to consider, first, what are the damages to vested property rights. It is found that the marshes which were flowed by tide waters before the building of the dam have shrunk and become lowered, in places varying from a few inches to half tide line. In allowing the tide waters to flow in over this area by the removal of the dam, this lowered area would be covered by salt water for so long a period over every tide that vegetation would be destroyed, and the area, as land, would be changed into mud flats, and become practically valueless. We are informed that about 1,031 acres of this marsh area is appraised, for the purposes of taxation, at $22,335. In view of Mr. Hersey's statements this must be considered a very low estimate; but applying this rate to the 1,334.3 acres which would be submerged, we have an appraisal of $28,900. The greatly increased volume of the ebb tide would require a wider as well as deeper outlet, and in making it the water would probably wash away the point jutting into the harbor from the south as far back as the bridge over Cut River, an estimated area of about 300,000 square feet, and with it some 25 cottages and a hotel, all valued at about $12,000.

The removal of the dam and dike and the substitution of a bridge suitable to replace such portion of the highway as may be destroyed, is estimated to require $27,200. The introduction of the increased volume of water, which, owing to the lowering of the meadows, would be considerably greater than before the building of the dam, would be attended by other unknown and possibly considerable injury to property, even though its flow were guided and controlled in a manner designed to avert the chances of unnecessary damage.

It cannot be foreseen in what precise locations or to what depth the ebbing tide of so great a body of water might disturb existing conditions. To guard against these possibilities and limit the course of the stream to insure a deep channel instead of a wide shallow channel, the construction of a jetty or training wall is undoubtedly necessary. The cost of this may be estimated to be not less than $40,000. The total expenditure, therefore, incident to the removal of the dam and dike, may be estimated to be the damages for the property injured, the cost of removing the dam and building a bridge, and the cost of a training wall or jetty to control the direction of the ebb

tides. These items together, excluding the damage to the meadows, will amount to at least the sum of $79,200.

The removal of the dike, however, is fortunately not the only solution of the problem. The mouth of Green Harbor empties into Massachusetts Bay in a general south-easterly direction. On the north-east it is protected by a point of rocks. The movement of the shore current which bears along the drift is from the south, and this has a tendency to close the river mouth. The dash of the waves in heavy weather, especially in south-easterly storms, brings more or less sand into the harbor. From the north-easterly storms the rocky promontory affords the harbor adequate protection.

The material which has filled up the harbor has probably come in from the outside from the south and south-east. The ebb current from Green Harbor proper has not been strong enough to preserve a channel of sufficient depth at low tide to answer the requirements of the vessels which anchor there. Under present conditions there is no reason to look forward to any improvement in the depth of the interior basin or the channel. Any change is more likely to result in gradual shoaling. A plan for improving this condition has been developed which it is believed will successfully preserve the usefulness of the harbor and increase its depth of water, both at the entrance, where a depth of from 30 inches to 4 feet at mean low water is desired, and in the harbor above, where the boats lie at their moorings.

This plan is to dredge an anchorage basin with a channel thereto, and to build two jetties and a training wall. An anchorage basin can be built above the Narrows by the dredging of an area of 90,000 square feet, which would be sufficient for all present requirements, and a channel dredged thereto from the sea, 50 feet wide at the bottom, leaving a depth on dredged areas of 4 feet at mean low water. In order to preserve this channel, it would be necessary to build a stone jetty from Duxbury Beach to deep water, to protect it from the sand drift and wave dash on the south and south-east. A small jetty on the north, running from the rocky point, would afford an additional means of maintaining the depth of the channel. In addition thereto, a training wall should be built inside the harbor to deflect and guide the current at the mouth of Cut River.

It is estimated that all of the work so planned will cost about $67,000.

By comparing this amount with the expense necessarily incident to the removal of the dam and dike, which, as above stated, amounts to $79,200, exclusive of the damage to the meadows, it will be seen that there will even be a saving in cost by constructing a harbor as proposed and leaving the dike undisturbed; but when we take into consideration the unknown and inevitable elements of damages, which must be considered if the dike is removed, the difference becomes a very serious one.

These elements of damages are found first in the diminution of health and attractiveness in the settlements along Marshfield beach, by reason of the foul odors brought over from the mud flats created by the flooding of the meadows to the west of them which are now below the level of high tide, and then by the absolute destruction of the fertile meadows which have been reclaimed by means of the dike. How large a sum of money is represented by these injuries, which will surely, we think, follow the removal of the dike, we are unable to estimate; but it will undoubtedly very much exceed the expenditure necessary to make a harbor sufficient for all the purposes of a fishing village, or an agreeable seaside resort.

We are then constrained to determine that the damage to vested property rights that would result from the removal of said dam and dike would be far greater than the benefit to Green Harbor resulting therefrom.

HENRY P. WALCOTT, *Chairman.*

WOODWARD EMERY,
CLINTON WHITE,
Board of Harbor and Land Commissioners.

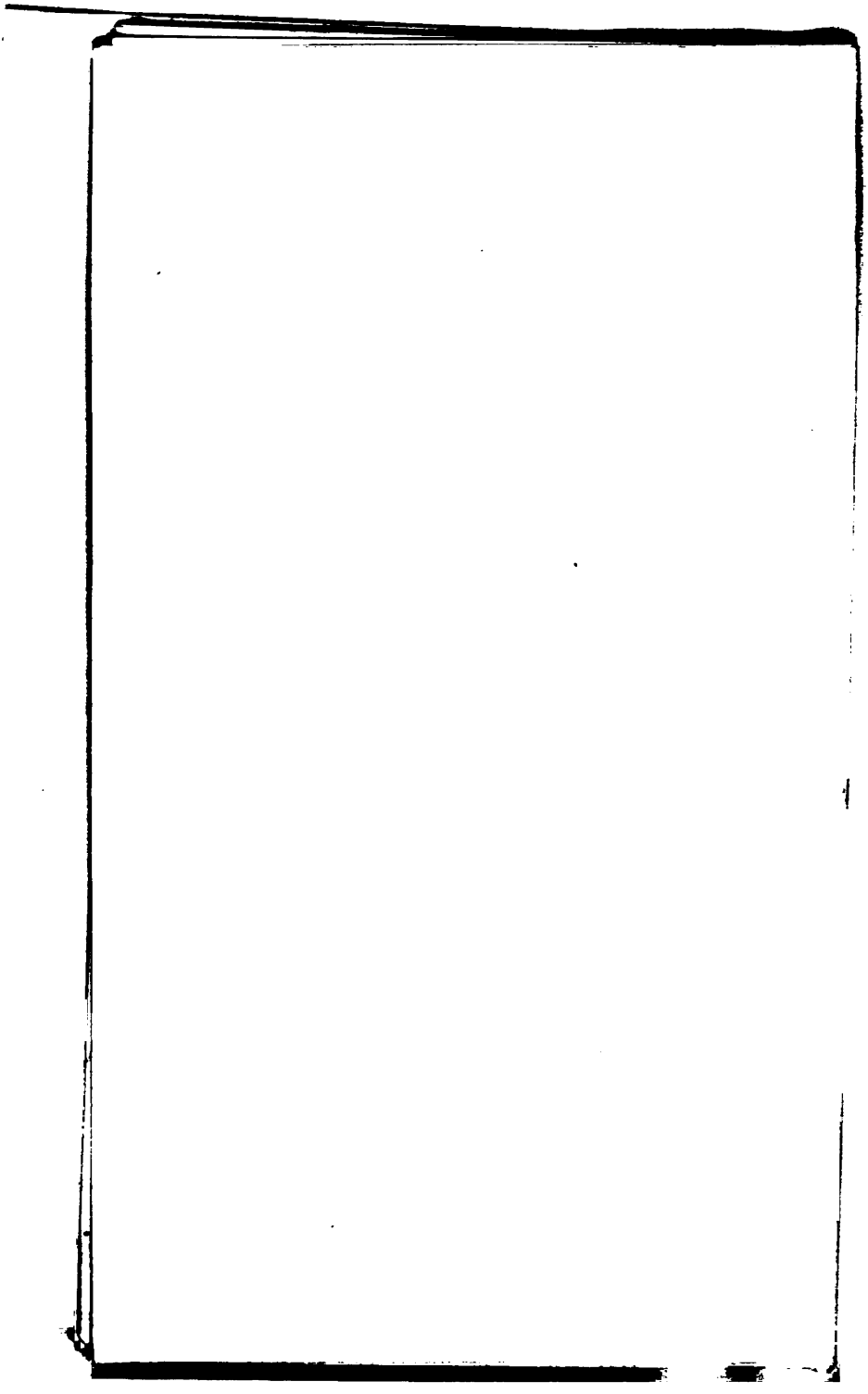
HIRAM F. MILLS,
FRANK W. DRAPER,
GERARD C. TOBEY,
JAMES W. HULL,
CHARLES H. PORTER,
JULIAN A. MEAD,
State Board of Health.

BOSTON, MASS., Jan. 5, 1898.

FINANCIAL STATEMENT.

Expenditures made under Chapter 495, Acts of 1896, and Chapter 98, Resolves of 1897.

Salaries of engineers, experts and assistants,	$7,750 43
Travelling expenses and subsistence of engineers, experts and assistants,	1,100 75
Labor, materials and supplies,	248 37
Travelling expenses of Joint Board,	105 18
Services of stenographers and typewriters,	129 10
Rent, fuel and use of boats,	190 85
Repairing instruments and tools,	29 70
Expressage and telephone,	31 99
Stationery, maps, postage and drawing materials,	46 55
Advertising,	12 70
	$9,645 62



APPENDICES.

Appendix No. 1.

State House, Boston, Oct. 12, 1897.

To H. P. Walcott, M.D., *Chairman of Joint Board on the Restoration of Green Harbor in the Town of Marshfield.*

Sir: — Herewith is submitted a report relative to Green Harbor, the Green Harbor marsh lands, and the dam and dike constructed across Green Harbor River under the provisions of chapter 303 of the Acts of 1871.

REPORT.

Green Harbor and the Green Harbor River and marshes are located in the south-easterly portion of the town of Marshfield. The lower portion of the river was at one time a tidal stream meandering through extensive salt marshes, which bordered the stream for a distance of about 6 miles from its mouth, and it received also the flow of a small water-shed, the total drainage area above its mouth being about 7.5 square miles. There are numerous summer cottages and a small fishing village along the shores of the ocean and harbor in the vicinity of the outlet, but the remainder of the water-shed contains no villages. The upland portions are inhabited by a scattered farming population, and much of the territory is wooded.

The marshes through which the river flowed lie just back of the sea-coast line, and extend from the vicinity of the mouth of the river for a distance of $2\frac{1}{2}$ miles in a north-westerly direction. Their inland limits are generally from $1\frac{1}{2}$ to 2 miles from the coast line, though a comparatively narrow strip along the river extends further inland. They are separated from the ocean by a barrier consisting of two areas of upland, known as Branch's and Hewitt's islands, and by sand and shingle ridges between the islands and north and south of them. Branch's Island, so called, extends from the northerly side of the mouth of the river nearly to the point called Brant Rock, and has a general width of some 600 feet. In the vicinity of Brant Rock the barrier between the marshes and the sea consists of a low shingle beach not over 300 feet in width, over which the sea is said to break at times. North of this is the high upland known as Hew-

itt's Island, forming a barrier along the sea for a distance of three-quarters of a mile, and extending back from the coast for nearly an equal distance. North of Hewitt's Island the barrier between the marshes and the sea for a distance of a mile consists chiefly of sand dunes, the distance from the edge of the marsh to the line of high water ranging from 300 to 800 feet. On the northerly side the marshes are separated from the marshes bordering the South River by a ridge of upland, and a similar ridge separates the Green Harbor marshes from the Duxbury marshes on the southerly side. Between the easterly extremity of this latter ridge and the southerly side of Hewitt's Island there is only a comparatively narrow strip of marsh land on each side of the river, and between these uplands, at a place a little over two-thirds of a mile from the mouth of the river, the dike authorized by chapter 303 of the Acts of 1871 was constructed and completed in the year 1872, to reclaim the marsh lands above for agricultural purposes, but leaving a considerable area of unreclaimed marsh land bordering the river below the dike. About the year 1879 a roadway was built by the town over this dike, which is now a county road.

Green Harbor may be defined as the portion of the river below the dike. Unreclaimed salt marshes border the harbor for a distance of about half a mile below the dike, having a maximum width of two-fifths of a mile on the north-easterly side, near the dike, but reducing to about half this width lower down; while on the south-westerly side of the harbor the width of salt marsh ranges from 250 to 600 feet.

The total length of the harbor from the dike to its outlet opposite Bluefish Rock is about 3,600 feet, or a little over two-thirds of a mile; and its length from the dike to the narrows between Washburn's Point and the northerly end of Duxbury Beach is about 2,500 feet, or a little less than half a mile. The width of the harbor just below the dike is about 500 feet. About 600 feet down stream from the dike there is a small island, and just below it a larger island about 800 feet in length. The river here has two channels, one on each side of the islands; the westerly channel having a minimum width at high water of about 325 feet and the easterly one a minimum width of 150 feet. Below the islands the harbor has a width of about 750 feet, reducing to about 600 feet just above Washburn's Point. In the narrows between Washburn's Point and the northerly end of Duxbury Beach the width at high water is only about 140 feet; but outside of the narrows the river widens at high water to the open sea, a rocky point, known as Bluefish Rock, being situated on the extreme point at the northerly side of the river's mouth, while at the southerly side the beach curves rapidly away toward the south. Just inside the narrows the harbor is joined by a creek from the south, known as

Cut River, the course of which lies parallel with and just back of Duxbury Beach. This stream enters the harbor at such an angle that its current is almost opposite that of the main portion of the harbor. Cut River drains the northerly portion of the Duxbury marshes, and is continuous to Pine Point River, an arm of Duxbury Bay, and the tide enters this channel in both directions. Observations show that the current in the stream at the beginning of the ebb divides, approximately, half-way between the two bridges over the stream in the rear of Duxbury Beach. The southerly bridge is known as the Rainbow Bridge.

At low water the portion of the harbor between the dike and the upper end of the large island remains covered with water. From this pond a channel from 40 to 60 feet in width follows around the south-westerly side of the island, and thence along the easterly side of the harbor to the inner side of Washburn's Point, where it turns toward the south-west, and then, turning a right angle, passes through the narrows in a south-easterly direction, its channel widening to about 100 feet, until it reaches the open sea just opposite Bluefish Rock. The shore on the easterly side of the entrance, from Washburn's Point to Bluefish Rock, appears to be composed principally of shingle, with sand filling in the voids between the stones; while the shore on the southerly side is an extensive sand beach, with a small amount of shingle.

The harbor is used by fishermen and summer residents for the anchorage of small yachts and boats. The crest of Duxbury Beach is covered with numerous small cottages, the most northerly one being within 200 feet of the extreme northerly end of the beach. This settlement is known as the village of Duxbury Beach, and the total number of houses upon the beach between its northerly end and the boundary line between Marshfield and Duxbury is 73, including 1 small hotel.

On the south-westerly side of the harbor and Cut River, and near the southerly extremity of the dike, is Green Harbor Village, which contains, largely, a permanent population, though the population is much greater in July and August than at other times, owing to the presence of summer visitors. The total number of houses in this village is 86, including 2 hotels.

On the north-easterly side of the harbor is the village of Brant Rock, the most densely populated portion being near the point known as Brant Rock; while a little farther north, along the shore side of Hewitt's Island, is the village known as Abington Village, or Ocean Bluff, which extends along the sea shore to the northerly limits of the marshes. Both Brant Rock and Abington Village are inhabited chiefly by a summer population, and contain very few people at other

seasons of the year. The total number of houses in Brant Rock and Abington Village is 329, including 4 hotels. In the early portion of the spring of 1897, the permanent population, principally fishermen and lobstermen, consisted of 61 people occupying 22 houses on the Brant Rock side of the harbor, and 112 people occupying 38 houses on the Green Harbor side. The maximum summer population in the two villages is probably in the neighborhood of 2,700.

In accordance with the directions of the Joint Board, we have caused surveys to be made of the meadows above the dike, to determine their extent, topography and elevation above mean low water of the sea, and have made examinations to determine the depth and character of the soil upon the meadows and the degree of saltness of the water of the streams by which they are drained. The condition of the dam and dike has been examined, and surveys and soundings have been made in the harbor from the dike to its outer limits. These surveys of the harbor have been repeated several times under various conditions, with a view to learning, so far as practicable in a limited period of time, what changes, if any, might be taking place in its contour. Surveys have also been made of the villages located about the harbor and along the shore between the meadows and the sea. Information has also been collected as to the condition of the harbor in the years before and since the construction of the dike.

Elevation and General Character of the Meadows above the Dike.

In making the surveys of the meadows above the dike, it was found that they had settled materially after reclamation, the surface of the meadows just above the dike being 2 feet or more lower than that of the unreclaimed salt marshes below the dike, which were found to be generally at or near the level of mean high tide. The dividing line between meadow and upland in the region above the dike was found to be approximately at the level of average high tide, which for this coast is 9.4 feet above mean low tide; and this level has been taken as representing the approximate limits of the former tide marsh above the dike. In some places, however, the meadow or meadowish land extends above this level, but its amount is small compared to the whole extent of the meadow. In addition to the apparent area reclaimed by the dike, it was deemed of importance, in connection with this investigation, to determine also the area of land which might be affected by extreme high tides, the limit of which, for this coast, has been taken to be at grade 13. The limits of the area of land which was found to have a surface level below mean high tide are shown in green upon the accompanying general plan (No. 2), and the area of

land lying between mean high tide and extreme high tide is shown between this green shaded area and the green line marked contour 13 on this plan.

The bulk of the area reclaimed lies between the dike and the place where the river is crossed by the New York, New Haven & Hartford Railroad. It is about 2½ miles in its general length in an easterly and westerly direction, and about 2 miles in a northerly and southerly direction. West of the railroad there is an additional area about 1½ miles in length and half a mile in its greatest width.

The surveys have shown that the total area of land above the dike which is below the level of mean high tide is 1,334.3 acres, excluding water surfaces, and the total area of both land and water surface within the limit of contour 9.4 above the dike is 1,443.7 acres. There are several small islands of upland surrounded by marsh, having an aggregate area of 15.8 acres, which have been excluded from the area as given above.

The elevation of the meadows varies considerably from place to place. Dividing them approximately, according to their elevation, it is found that the areas of meadow land between certain elevations are about as shown in the following table, water surfaces being excluded: —

	Acres.
Area between grades 9.4 and 8.4, or between high water and 1 foot below,	283.3
Area between grades 8.4 and 7.4, or between 1 and 2 feet below high water,	471.4
Area between grades 7.4 and 6.4, or between 2 and 3 feet below high water,	534.7
Area below grade 6.4, or more than 3 feet below high water,	44.9
Total below grade 9.4 (mean high tide),	1,334.3

The area between grade 9.4 and grade 13, which has been assumed as the approximate level of extreme high tides along this coast, is 361.7 acres, making the total area of land that might be covered at extreme high water, if the tide could enter freely, 1,696 acres.

The character of the surface of the meadows is quite varied, a large proportion, amounting to about 37 per cent. of the whole, being mowing land, of which one-third, or 12 per cent. of the total area of the meadows, appears to be good mowing land, from which large crops of hay are harvested. The remainder, amounting to about a quarter of the whole area of the meadows, has a somewhat less smooth surface than the lands just mentioned, and apparently furnishes a poorer yield of hay. There are several areas of cranberry bog, aggregating in all 25 acres, the largest bog being near the southerly

side of the meadow. An area of about 16.2 acres of the meadow near the latter bog and next to the upland is used as a reservoir to store water for flooding the bog. Only a very small area, amounting to a little over 2 acres, was found to be utilized for the growing of garden crops at the time the surveys were made. About 18 per cent. of the whole area is covered with bushes and trees in various stages of growth, large areas being covered with white birches 20 to 30 feet in height, while other areas are covered with smaller trees of various sorts. The remainder of the area, aggregating about 41 per cent. of the whole, is apparently used largely for pasturage. Large portions of this area are covered with weeds and coarse grasses, and about 100 acres contain also clumps of bushes. Summarizing the areas described as well as practicable, the total area of each kind of land at the time the surveys were made was about as follows: —

	Acres.
Mowing land,	498.6
Cranberry bogs,	25.0
Garden lands,	2.1
Pasture lands,	550.9
Wooded areas,	241.5
Area used as a reservoir for flooding cranberry bog,	16.2
Total,	1,334.3

Near the upper end of the meadow, just below the highway bridge, there is an area of about 60 acres, containing numerous large stumps partially decayed, as well as a considerable growth of young trees. The stumps are the remains of a forest, principally of white cedar. There are a few other small areas of such land in other portions of the meadows.

There are small patches about the meadows almost entirely devoid of vegetation which are known as bald meadow. On the surface of some of these there was a whitish crystalline material, which, upon analysis, was found to be composed largely of salt. The largest of these areas is probably less than an acre in extent, and they are usually very small, so that it has not been practicable to take account of them.

The character and depth of the soil of the meadows has been examined by means of numerous soundings and test pits distributed generally throughout the area of the meadows. From these it appeared that in the easterly portion of the meadows, along the lower reaches of the river, the surface was composed of a layer of turf and soil from 6 inches to 1 foot in thickness. Beneath this layer the soil for a depth of from 1 to 3 feet consisted of earthy and fibrous matter, in some places the earthy matter appearing to predominate, while in others the material

appeared to be largely a mass of small fibres; beneath this layer the subsoil was found to consist largely of clay mingled with more or less fibrous matter. At the upper end of the meadows, and at several places about the sides, while the surface turf and soil resembled that in the lower portions, the layer of fibrous matter beneath was of a more peaty nature and the subsoil was muck, in some cases resembling peat. Throughout the meadows the soil either of clay or muck was underlaid by sand. The average depth at which this sand was found below the surface was about 8 feet, and the maximum depth at several places was found to be between 20 and 25 feet. The area having a substratum of clayey material comprised about 761 acres, or 57 per cent. of the total area of the meadows, while the areas having a substratum of peat aggregated approximately 573 acres. The peaty areas, as already stated, were located largely at the upper end of the meadows, approximately above a line drawn across from north to south a little west of the first farm bridge above the dike; but there was in addition a considerable area in the south-westerly portion of the meadows, another in the northerly portion, and also small areas in the southerly portion in the vicinity of the dike, and westerly from it along the southerly edge of the meadows. In a general way it may be said that, where equally well drained, the surface of the meadows was found to be lower where the peaty soil extended to a considerable depth; but in the upper end of the meadows, where the water in the stream is at a higher level, this difference was not apparent. In some places along the edges of the streams the land was found to be considerably higher than a short distance back from their banks, and this soil generally contained a considerable quantity of sand.

There are several buildings, chiefly barns, of various sizes on the diked lands, mostly located in the easterly portion of the area. The total number located on land below grade 9.4 is 19, and there are 13 others between grade 9.4 and grade 13.

The Dike.

The dike, as already stated, is located a little over two-thirds of a mile from the mouth of Green Harbor, at a place where the upland approaches the river on both sides. The total length of the dike is about 1,600 feet, and its top is nearly level and is at about grade 14.6 above mean low water, the lowest depression being at grade 13.1 and the highest place at grade 15.2. The bottom of the river in this vicinity is about 6 feet below mean low tide, and the river has a width of about 500 feet. The dike has an average width at the top of about 22 feet, and forms the roadway connecting the villages of Green Harbor and Brant Rock. It is said that originally its width was much less, but that it was widened by the construction of the road in

1879. From such information as has been obtained as to the construction of the dike, it appears that sheet piling was driven in a line across the river, and that the piling was surrounded by a filling of stones and gravel. It appears also that during construction the tide passed through a flume which was subsequently closed by stop-planks, and the whole covered with stone and gravel filling. Two sluices were laid through the dike, each 4 feet high and 3.5 feet wide inside, and having the bottom at the upper end at about grade 1.61 and the lower end at about grade 1.56 above mean low water. The capacity of the sluices is, however, reduced by upright timbers 4 inches thick, placed at intervals of about 4 feet along their inner sides. At the outer end of each of the sluices are tide-gates which are closed automatically by the tide when it rises above the level of the water inside the dike, and are designed to keep salt water from passing through the sluices from the harbor to the river above the dike. In addition to the tide-gates at the outer end, there is also a tide-gate in each flume not far from its inner end, apparently introduced subsequently to the construction of the dike, to assist in keeping out water from the harbor when the tide is higher than the level of the water inside the dike. At the end of each of the sluices, on the inner side of the dike, is a sluice-gate designed to control the level of the water in the river above the dike.

It appears to be the practice to leave these sluice-gates partially open at all times, and to raise or lower them only at infrequent intervals, whenever it is desired to raise or lower the water in the river above the dike.

Judging from observations made upon the level of the water during the time covered by these investigations, it appears that the water above the dike in the summer season, in an ordinary year, may be kept down to a level about 0.3 of a foot above the average of low water just outside the dike, the level of low water in this portion of the harbor being found to average about 3.5 feet above mean low water at the outlet of the harbor, from causes which will be described in a subsequent portion of this report.

In a wet season the water inside the dike apparently stands at a somewhat higher level, and in the winter and early spring months the water is kept at a much higher level than in the drier portion of the year. During the time when the tide outside the dike is above the level of the water inside there is a large leakage of salt water through and around the flumes into the river above the dike, and at times of spring tides there is also a leakage through the dike at several other places. At one of these places a considerable stream can be seen flowing through the dike at such times.

Observations have been made to determine the amount of leakage,

and the results show that with an ordinary high tide it may amount to about 150,000 cubic feet at each tide, when the level of the water in the river above the dike is at about grade 4.7 above mean low water. With a lower level of the water above the dike the quantity of leakage is probably somewhat larger, both on account of the greater length of time that the leakage would continue and the greater head upon the water leaking through the dike.

Drainage.

The main drain of the meadows is the Green Harbor River, which drains an area above the dike of about 6.9 square miles, as measured from the State map. The fresh-water flow is very small in the summer season, and before the dike was built it probably had very little effect upon the flow of the river in the lower portion of the meadows. The river just above the dike is fully 500 feet in width; just above Wharf Creek, at a point 2,200 feet from the dike, its width is about 350 feet; and just above its confluence with Bass Creek, about a mile from the dike, its width is about 125 feet. Its width gradually decreases, going up stream, to 40 feet at the first farm bridge above the dike and to 20 feet at the second bridge. Bass and Wharf creeks are the two principal tributaries. Wharf Creek joins the main river about 2,000 feet above the dike, and drains the southerly portion of the meadows; Bass Creek joins the main river at a point about a mile above the dike, and drains the northerly portion of the meadows. The main river has a very crooked course from its upper end to Bass Creek, and there are numerous branch creeks extending from the main stream and its two principal tributaries into various parts of the meadow.

The bed of the main river is below the level of low tide for a distance of about 2 miles above the dike, where there is a small bar which rises about 1 foot above low tide. The bottom is lower above this bar, however, and up to within 1,800 feet of the first farm bridge over the river the bottom is below low water. Above this point it rises gradually to the highway bridge, where it is about 4 feet above low water. The bed of Wharf Creek is below low water for a distance of about three-quarters of a mile from its mouth, while the bed of Bass Creek is below the level of low water for considerably more than one-half mile from its junction with the river.

The height of water in the main river has been observed on several occasions. Owing to the large size and depth of the main stream through the greater portion of the meadows and the small size of the water-shed, the surface of the water in the main river is practically level for a long distance back from the dike, but toward the upper end of the meadows there is considerable slope to the water. On

observing the slope of the stream at a time when its flow probably represented an average summer flow and the height of the water at the dike was about 1 foot higher than the level at which it can be kept under ordinary conditions in the summer, it was found that there was practically no difference in the level of the surface of the stream between the dike and the second farm bridge above the dike, a distance of 18,000 feet following the course of the stream. Above this point the stream had considerable slope, and the surface of the water at a point two-thirds of a mile above the second farm bridge and one-half a mile below the highway bridge was found to be .2 of a foot above the level of the water at the dike; while at the highway bridge near the upper end of the meadows the water was .85 of a foot above the level of the water at the dike, and stood at about grade 5.5 above mean low water. Above the railroad bridge, 200 feet above the highway bridge, the water was found to be .7 of a foot higher than at the highway bridge, its surface standing at grade 6.2, or about 1 foot below the surface of the lower portion of the meadows in this region.

The chief cause of this steep slope between the bridges is due to obstructions in the bed of the stream, and the water above the railroad bridge could be lowered materially by removing the obstructions between the bridges. For a considerable distance below the highway bridge the flow of the stream was obstructed by weeds and bushes, and a considerable lowering of the surface of the water might be effected by removing these obstructions. At a time of high flow in the spring, when the water at the dike was about 1 foot above the ordinary summer level, the water in the river above the dike was found to have a fall of about .09 of a foot between the second farm bridge above the dike and the dike itself, about half of this fall occurring between the second bridge and the first bridge above the dike. The water at the highway bridge at the upper end of the meadows at this time was found to be nearly a foot higher than at the time of a low summer flow.

The river and its tributaries with the branch creeks serve as main drains for the meadows, and drainage has been somewhat further facilitated by ditches in portions of the meadow, and much of the area has a firm surface and is well drained. Ditching has not been general, however, nor are the ditches well cared for; and around the sides of the area and toward the upper end, especially above the second farm bridge reckoning from the dike, there are considerable areas that are poorly drained, there being few ditches, and the water stands upon the meadows in places during the wetter portion of the year. This is especially true of the stump meadow already referred to, in which little or no ditching appears to have been done, and the

surface is generally soft and wet. It may be added that this area is at a generally higher level than any other considerable portion of the meadows. Above the railroad bridge also the drainage of the land is poor, and this area resembles in its general characteristics a fresh-water meadow.

Degree of Saltness of the Water of the Meadows above the Dike.

Numerous samples of water have been collected from the stream and ditches in the meadows above the dike at different seasons of the year, to determine the quantity of chlorine present.

For a distance of about a mile on the north-easterly side the meadows are separated from the sea by ridges of sand, and occasionally at times of very high tides during heavy storms some sea water flows through depressions between the sand hills, and thus enters the meadows. The places through which it enters are quite narrow, and, as the bottoms of these depressions are at the lowest about 13 feet above mean low tide, the water can flow through them only for a limited time. The quantity of salt water which enters the river above the dike in this way, therefore, is very small, as compared with the leakage through the dike, though an overflow took place on one, and possibly two, occasions during the time covered by these investigations.

Chemical examinations of the water of the creeks have shown that at all seasons of the year the water in the bottom of the main river and the larger creeks, where the depth is such that the bottom is below low water, or but little above it, is composed largely of sea water. The chlorine of the sea, as determined from several analyses of water collected in this region, is about 1,740 parts per 100,000, and from the analyses of samples collected from the bottom of the creeks, the latter is generally about 70 per cent. sea water. In December and April, when the flow from the water-shed above the dike was probably much above the average for the year, and the river and creeks were free from ice, the chlorine at the surface of the river between the dike and Bass Creek was found to range between 170 and 290 parts per 100,000. The chlorine in Bass Creek in April was considerably higher than was found in the main stream above Bass Creek or in Wharf Creek, which may possibly have been due to an extra amount of salt water entering the creek during a winter storm by running over the beach. When the river was covered with ice, in February last, samples collected from the main river between the dike and a point about 3,000 feet above the dike and just beneath the ice, were found to contain much less chlorine than at other times,

the quantity ranging between 2 and 10 parts per 100,000. In August the chlorine at the surface of the main stream was found to range between 450 and 700 parts per 100,000, the chlorine at the bottom remaining about the same as at other seasons.

It appears from these results that the quantity of chlorine at the surface of the water in the river and larger creeks is affected by the winds and by the flow of fresh water; since, when the wind cannot touch the water, at times when it is covered with ice, the water just under the ice is nearly fresh; whereas in the summer season, when the flow of the streams is low and there is much evaporation and a considerable mixture of the water by the winds, the chlorine at the surface of the river is higher than at other times. In the tributary creeks a considerable variation was found in the quantity of chlorine present in the water. The water as it passes through the highway bridge at the upper end of the meadows contains only about 3 parts of chlorine per 100,000, which is probably not much above the normal for this region. Similar amounts are found at the upper ends of the smaller creeks in various parts of the meadows. Lower down the creeks the quantity of chlorine found is generally larger, and in the larger creeks not far from the main river the chlorine is sometimes greater than the chlorine at the surface of the main river, — due probably to the fact that the creeks are shallow, and that there is a more thorough mixture with the salt water at the bottom, caused by the wind. So far as these examinations have shown, the chlorine of the tributary creeks, where they appear to be unaffected by salt water from the larger creeks, is generally not much over 100 parts per 100,000 at any place.

The chlorine in the smaller creeks is found to vary, however, at different seasons of the year, in the summer season being generally higher than in other portions of the year. The results of the investigations indicate that in some places the quantity of salt in the soil is very low, while in others a considerable quantity of salt still remains; but the soil in the greater portion of the meadows does not appear to contain an excessive quantity of salt.

Probable Effect upon the Meadows of Flooding them again with Salt Water by removing the Dike.

Very little information is obtainable as to the elevation of the meadows above the dike at the time the dike was constructed. It is stated in the report of Prof. Henry Mitchell, who made the original surveys of these lands before they were diked, that the marsh in the vicinity of the dike was at about the level of high tide; and levels taken upon the marshes below the dike show that at the present time

the elevation of their surfaces varies from place to place and may average 9.1 feet above mean low tide, while the surface of the meadows just above the dike is between grade 7 and grade 7.5. The marsh between the two roads leading to Duxbury Beach is higher, and so is the north-easterly portion of the Duxbury marsh, the surface of the former being at about grade 9.2 and of the latter at about grade 10.

The sharp contrast between the elevation of the marshes just below the dike and that of the meadows just above it leaves no doubt of the subsidence in the level of the meadows in this vicinity. No information showing the former height of the meadows in their upper portions has been found, but it is probable that they were at about the same level as the marshes below the dike. Levels taken upon the upper portion of the Duxbury marshes show that their level is about the same as at the lower end. The marshes along the South River north of Green Harbor marshes are found to be lower than the Duxbury marshes, and in the upper portions they average about grade 9, or about the same level as the Green Harbor marshes below the dike.

If the dike should be removed and the salt water allowed to enter freely upon the meadows, as it did before the construction of the dike, the conditions would now be very different from what they were previous to its construction. The larger portion of the meadows above the dike would be flooded to a depth of 2 feet or more at ordinary high tide, and at spring tides, occurring for several days each month, to a depth of 4 feet, and at times of high storm tides to a greater depth. The greater portion of the meadows would be covered with salt water for two periods of about four hours in each twenty-four hours, and would be uncovered for two periods of about eight hours each.

An examination of the vegetation upon the reclaimed meadows shows that practically all of it is that of a fresh-water region, and the effect of flooding the meadows would be the destruction of practically all of the present vegetable life upon the area covered by salt water. As has already been shown, there are somewhat more than 240 acres of wooded land situated below the level of grade 9.4, and there are, besides, about 100 acres covered with weeds and grasses mingled with bushes, making a total of 340 acres of wooded and partially wooded land which would be flooded by average high tides. There are, moreover, about 320 acres of land covered with very coarse tall grasses and weeds, making a total of 660 acres which are covered with a growth of vegetation that, if killed by salt water, — as most if not all of it undoubtedly would be, — would give the marsh a most unsightly appearance.

The large areas of mowing land also would be converted, for a

time at least, into a condition resembling mud flats covered with organic matter. The portion of the meadow above the railroad, amounting to 10 per cent. of the whole area, could be kept from being flooded by the tide at a small cost by constructing a small dam or dike at the railroad or highway bridge, and it is possible that other small areas could be saved from flooding by the construction of dikes and sluices; but the total area which would be subject to flooding below grade 9.4 is not likely to be less than 1,150 acres.

Moreover, at times of spring tides a considerably greater area would be flooded. The area, as already indicated, between grade 9.4 and grade 13, surrounding the meadows, is 361.7 acres, of which about 302 acres are in the region below the highway bridge at the upper end of the meadows, and it is probable that the existing vegetation over the greater portion of this area also would be killed by the salt water.

Whether the condition of the meadows would revert to what it was before the dike was constructed, — that is, whether they would again become salt marshes with the surface at about the level of high water, — and if so how long a time would elapse before this condition would be reached, are questions to which much attention has been given, and information has been sought from various sources as to whether reclaimed marsh lands under similar conditions have ever been abandoned to flooding by the tides by the destruction or removal of a dike, as is proposed in this case, and the effect of such flooding on the elevation and condition of the lands. No instance has been found, however, where an area like that at Marshfield, containing a large amount of fresh-water vegetation, has been flooded with sea water, which might serve to show definitely what changes in the condition of these meadows might be expected to take place after the removal of the dike.

The reclamation of marsh lands subject to flooding by the tide has been largely practised in Nova Scotia and New Brunswick, and in New Jersey and Delaware and vicinity on the Atlantic coast of North America; while in Europe are the well-known diked lands of Holland and England, which cover far more extensive areas than any in North America. There are also instances where small areas of tide marsh have been reclaimed at several places along the New England coast. The greatest areas of reclaimed marsh lands on this side of the Atlantic are in the vicinity of the Bay of Fundy and its various arms. So far as can be judged from information obtained concerning these lands, the conditions differ materially from those at Marshfield. The tides in this bay rise generally to a much greater height than at Marshfield, and are said to carry a very large amount of silt and mud in suspension, which is deposited when the water is allowed to spread

out over a large area. The diked lands are highly cultivated, and appear to settle after diking; but it has been found that their level can be maintained and the fertility of the lands increased by flooding them with tide water from time to time, owing to the large amount of muddy sediment deposited upon them by the tide. The conditions differ so greatly from those at Marshfield that the experience furnished by flooding the diked lands in the region of the Bay of Fundy is not applicable to the lands at Marshfield.

Along the Delaware River and Bay and their tributaries, especially in New Jersey and Delaware, there are large areas of diked lands. The tides here have a mean range considerably less than those at Marshfield, and the conditions in other respects are very different. The lands are generally located near the mouths of large rivers, where the water is only partially salt and is sometimes nearly wholly fresh, and the waters carry in suspension a very large amount of silt or mud. The soil of some of the diked lands in this region appears to be about the same in character as that at Marshfield, and the lands settle when diked and thoroughly drained; but it has been found that the level of the lands can be raised and their fertility increased by opening them to the tide, and thus securing a deposit of sediment from the tide water. The rate of deposit varies; in some places it is said to be very rapid, so that a deposit of from 1 to 2 feet may be obtained in little more than a year, while in others the deposit takes place so slowly that from five to ten years may be required to raise the level of the meadows as much as 2 feet. The rise in the level of the meadows appears to be due entirely to the deposit of sediment upon their surfaces; and the length of time required to secure this deposit, in cases where the quantity of sediment in the water is small, would indicate that there is little if any rise in the level of the meadows after flooding from any other cause.

The water of the sea which would enter the diked lands at Marshfield is not a muddy water, and, excepting particles of fine sand, contains very little suspended matter; and it cannot be expected that any noticeable rise in the level of the meadows will take place by deposits from the sea water for many years, — except possibly at the extreme lower end, where the slackening of the rapid current of the incoming tide might cause a deposit of sand.

Information has also been obtained relative to the abandonment of reclaimed tide marsh lands at several other places along the coast, but in these cases the areas appear to have been much smaller than at Marshfield, and there is no evidence as to whether the lands had settled materially or not. In most of these cases the lands appear to have been abandoned in a few years after reclamation, and for this reason it is doubtful whether any material settlement had occurred,

and it is for the same reason unlikely that they were covered with trees or other vegetation to such an extent as the diked lands at Marshfield. It may be added that such information as has been obtained as to these small areas of abandoned diked lands would indicate that they were practically devoid of vegetation for several years after being opened to the tide before they returned to their former condition.

Within the limited time available for the investigation of the subject, it has not been feasible to make experiments at Green Harbor upon such a scale and to continue them for such a period of time that they might serve of themselves to show what changes may take place in the elevation and condition of the meadows by flooding them with sea water under conditions similar to those which would be produced by the removal of the dike.

Before the construction of the dike the meadows were kept in a saturated condition by the tide, but after the tide was shut out the water appears to have been kept at a level several feet below their surface, and the conditions under which the vegetation had formerly existed upon the marshes were changed. This change in the water level probably caused the great difference which is now observable between the condition of the materials composing the layers of soil above the new water level, which is 5 feet or more below the level to which the water formerly rose at each tide, and the condition of the materials at a corresponding depth in the salt marshes below the dike. No chemical test will show the difference between the condition of the soil of the reclaimed lands above the dike and that of an ordinary salt marsh so well as a simple inspection. The soil, both of the salt marshes and of the meadows above the dike, contains a large amount of small roots and fibre. In the numerous samples of the soil from the meadows above the dike that were examined, the roots were found in nearly all cases much discolored and decomposed, while in the samples examined from land below the dike the roots and woody fibres were bright and clearly in a state of vigorous life and growth. The shrinkage in the meadows appears to be due to the draining of the water out of them and the subsequent decomposition of the roots and fibres of the soil, which allowed the soil to become more compact; and it is very probable that practically all of the shrinkage has occurred above the present water level in the river and creeks.

In order to obtain such experimental information as was practicable within a limited time as to the probability of the marshes rising after flooding, two sections of soil, each 20 inches in diameter and 3½ feet deep (which is the average depth of soil above the present water level), were cut from the meadows above the dike and taken to the

experiment station of the State Board of Health, and there treated by flooding with sea water twice a day for about the time that the meadows would be flooded if the dike should be removed. One of these sections was taken from near the lower end of the meadows, where the subsoil is of a clayey nature, and this sample was representative of the greater portion of the area of the meadows. The other was taken from toward the upper end of the meadows, and was representative of only a small portion of their total area, but was selected because the soil was of a kind which appeared to be the most likely to expand by flooding with water. The experiment upon the first sample, after being continued for a period of about three weeks, showed hardly a perceptible increase in the size of the cylinder of soil, the greatest variation shown by any of the measurements being about 1-16 of an inch. The experiment upon the second sample showed, in the beginning, that when flooded the surface would rise about 2 inches, but it immediately settled again after the water was allowed to drain out of the soil for a period corresponding to that between high and low tide. After the samples had been flooded for several days, the surface of each became covered with a rank mouldy growth, and the soil had a very strong and offensive odor.

The results of these experiments, which are described more fully in the report by the chemist, Mr. Clark, indicate that the soil in the meadows is not likely to rise after flooding by the tide, excepting possibly to a slight extent over a very small area, unless after the lapse of a considerable time.

Another experiment was made by diking a section 15 feet in diameter in the lowest portion of the meadows, the soil of which is representative of a large portion of them, and flooding it daily with water from a neighboring creek above the dike, careful levels being taken upon the area before flooding and at different intervals after flooding. This experiment has been continued for more than two months, and the levels fail to show any rise in the surface of the meadow.

An indication is also furnished by an area which is used for storing water for flowing a cranberry bog. This area has been flooded from time to time for several years; but levels taken upon it at the time when it was flooded during the past winter did not show that its surface differs materially in elevation from that of other portions of the meadow in the vicinity which are not subjected to flooding.

Judging from the information furnished by experience with the flooding of diked marshes in other places, and from the examinations and experiments referred to above, it does not seem to be likely that the flooding of the reclaimed meadows with salt water by the removal of the dike would produce any material rise in their level by

a swelling of particles composing the soil, for many years in the future, if at all; and, as already indicated, there is no considerable amount of suspended matter in the sea water which would be likely to cause a rise in the level of the meadows by forming a deposit upon their surface, nor will any material amount of silt be brought into the meadows from the very small streams which enter them, though it is probable that small amounts of seaweed and kelp will be brought in by the tide and deposited upon the meadows from time to time.

If the meadows had not settled at all, the indications are that by the removal of the dike the present vegetable life would be largely destroyed, and that it might be several years before a salt-water vegetation would replace it, though they would be likely to return to their original condition in time. But, if the meadows remain at or near their present elevation, as seems likely to be the case for an indefinite time, we see no reason to expect that they will revert to their original condition, at least for many years.

The condition of the lands above the dike after being opened freely to the tide would be likely, for several years at least, to resemble that of mud flats covered with organic matter, and they would not only be unsightly on account of the large areas that would be covered with dead trees, bushes and other vegetation, but they would also very likely give rise to offensive odors, especially in the summer season, on account of the presence of so much decaying organic matter upon the surface, which would be flooded twice a day and subsequently exposed to the action of the sun and air. There are instances where serious trouble has been caused by deposits of organic matter of comparatively small area upon extensive mud flats. An offensive odor from an area of mud flats in the vicinity of Boston harbor, where the water covering the flats was found to contain little or no sewage, was upon investigation found to come from deposits of organic matter aggregating not more than 6 acres, though the whole area of flats was about 300 acres. In a small harbor on the south-easterly coast of the State, where the water is unpolluted by sewage, a deposit of seaweed and similar matters of marine origin near the shores of the harbor produces very offensive odors in the neighborhood at times of low water in the summer season.

It will also be noted that, in the course of the experiments upon the sections of soil from Green Harbor already referred to, it was found that there was a rapid growth of microscopical organisms upon the surface of the soil which was flooded with sea water, and that the soil gave off a very offensive odor after being flooded for a short time. If offensive odors should arise from the marshes after flooding them with salt water, as it seems probable will be the case, the nuisance will be felt most seriously by the inhabitants of the villages

along the shore and near the mouth of the harbor, since the prevailing winds in this region in the summer season, which are from south-west to north-west, will blow over the meadows in the direction of these villages. Moreover, a change of this great area from its present condition to that of a mud flat covered with organic matter and alternately flooded with water and exposed to the sun and wind might not only cause a serious nuisance from odors arising from it, but might also prove unfavorable to the health of those living in its vicinity.

Character of the Harbor and Changes which have taken Place since the Construction of the Dike.

It appears from the tenth annual report of the Harbor Commissioners that petitions were presented to that Board in 1875, alleging that shoaling had taken place within the limits mentioned in section 4 of chapter 303 of the Acts of 1871, and praying for the relief therein provided. The report of the Board with reference to this matter, dated January, 1876, is as follows: —

The Board, with its engineers, visited the harbor in August, and inspected its condition at various stages of the tide. A partial hearing was given at that time to the petitioners and such meadow owners as appeared, and subsequently in Boston a more extended hearing was had, at which testimony was introduced on both sides, and the views of the different parties interested were ably presented by counsel. The harbor has suffered a decided injury from closing the tidal reservoir which the marshes afforded. The channel of the river and its approaches was formerly cleared by the daily scouring of the outgoing tide, so that boats drawing two feet could enter freely at all stages of the tide, but now the bar at the entrance does not admit of sufficient depth at low water for the use of boats of any description. Shoaling has undoubtedly taken place both in the channel and its approaches above mean low water. Natural causes have contributed to this shoaling to some extent, and it would not be practicable to separate with precision the results of natural causes from the results of the dike, but it is clear that what has occurred must be mainly attributed to the dike. A further survey will be necessary to determine the extent to which the obstructions should be removed to meet the requirements of the statute, which survey will be made as early as the weather will permit.

In the eleventh annual report of the Harbor Commissioners, dated January, 1877, it is stated that a survey had been made in the previous year of Green Harbor River in Marshfield, including the bar outside the headlands of the harbor or anchorage basin, and the part of the river above the basin and below the dike erected in the year 1872. They also state that the plane of mean low water for this

vicinity was determined and permanent bench marks established at Green Harbor; and it may be stated here that the bench marks were found, and that all the levels of the recent survey refer to this base. With regard to the condition of the harbor as shown by the survey of 1876, as compared with its condition as shown by the survey of 1857, the Board report as follows: —

The high-water outline of the beach, harbor and river, from Bluefish Rock to the dike, with some marginal topography, have been surveyed, and points identical with those of the United States Coast Survey of 1857 determined sufficiently well to give a basis for the comparison of the high and low water lines of the two surveys. The contours of the bar, channel and bed of the harbor basin, as far up as the lower end of the first marsh island, have been determined by numerous level stations.

At the time that the project for the dike was under consideration, no survey of the bar and mouth of the river was made. As far as could be observed, the Coast Survey map still represented the general features of the topography, and no change decidedly detrimental to navigation had occurred. No soundings were furnished upon the map just mentioned; but by inquiry of fishermen the surveyors satisfied themselves that the harbor proper had remained essentially the same, while it was manifest that a considerable increase of the beach separating Cut River from the sea had taken place, and this seemed to threaten the entrance as a remote possibility.

As has been said, no soundings are furnished by the topographical map of the Coast Survey (1857), and therefore the estimate that will be furnished first given of the *total* deposit which has taken place in the interval between the two surveys is only an approximation, but a safe one, it is believed, in the respect that it is not an exaggeration. Portions of the two maps which have been compared may be distinguished as the *basin* and the *bar*, — the former being the space between the Narrows at Washburn's Point and the first marsh land above, about 8½ acres as limited by the low-water lines of 1857; and the latter, the low-water space of 13¾ acres (1857) seaward of the Narrows, limited by the arc of a circle passing through the extremity of Bluefish Rock, — the said circle having a radius of 1,900 feet, with its centre at the outer end of the first wharf or stage now existing at Cut River Village.

In the basin, as above described, the total deposit amounts to about 52,000 cubic yards since the dike was projected; and on the bar the total deposit since 1857 amounts to 106,000 cubic yards. The amount deposited in the basin above *the plane of mean low tide and beyond the low-water lines*, as they existed before the dike was projected, amounts to 23,000 cubic yards; while the amount similarly deposited on the bar since 1857 amounts to 63,000 cubic yards.

It would be unwarrantable to attribute the whole accumulation over the spaces examined to the reduction of the tidal scour, which was formerly strong enough to keep the entrance free. The very fact that there are such great volumes of sand drifting along the coast, ready at every flood tide, or inroad of strong seas, to enter all the rivers and creeks, might lead one to

expect that gradually all basins (as distinguished from channels) are to be filled up. The case of Plymouth harbor, in this very neighborhood, is the best illustration. The recent Coast Survey chart, compared with those of the seventeenth and eighteenth centuries, shows that many millions of cubic yards of sand have accumulated in the main ship channel and in the bay below Brown's Island (see a report on the physical history of Plymouth harbor, in Appendix). Moreover, some observations made by the Coast Survey during the past year, being compared with others of previous years indicate that in the portion of Cape Cod Bay, adjacent to the neighborhood under examination, there is a meeting of very peculiar coast currents bearing material for shoal-building.

The Board, after carefully considering all the possibilities of the case by the light of the recent surveys and studies of its engineers, saw no sufficient reason to change the opinion, expressed in the report of last year, "that what has occurred must be mainly attributed to the dike." An order was therefore issued directing the removal of the accumulation, or so much of it as may be necessary to secure a channel for the passage of boats and small vessels.

Copies of the plans showing the surveys and soundings of the harbor in 1876, four years after the construction of the dike, are on file in the office of the Harbor and Land Commission. They are plotted to a scale of 100 feet to an inch. The topography is shown from a point just above the dike to Bluefish Rock on the north, and on the south to a point on Duxbury Beach just south of the road from Green Harbor Village. The soundings, or levels, give the elevations of the bottom from the lower end of the large island in the harbor, through the Narrows to the outer end of the low-water channel near Bluefish Rock; but no soundings were taken in the upper part of the harbor, between the lower end of the island and the dike, a distance of about 1,500 feet.

In 1878 and in 1880 the engineer of the Harbor Commissioners visited the harbor and sketched on the plan of the survey of 1876 the inner edge of the sand bottom within the harbor, and these sketches indicate that the bottom of the harbor was being covered with sand at a rapid rate, the edge of the sandy bottom having advanced between 1876 and 1880 from just below the lower point of the island nearly to its upper end, a distance of about 800 feet; but no measurements which would indicate the amount of filling were taken at the time of these visits.

Since August, 1896, we have had surveys made of the harbor and have made a plan showing its condition at the present time, on a scale of 100 feet to an inch, the same as that of 1876. A reduced copy of this plan is presented herewith (Plan No. 3 The plan shows the high-water lines of the harbor and its immediate tributaries, with the location of the roads and buildings near it. It also

shows the elevation of the marshes and of the bottom of the harbor and of Duxbury Beach from the dike out to deep water in the bay. Measurements were also made of the velocities of the tidal currents at a number of places in the harbor. The topography of the bottom of the harbor and the levels over it have been surveyed twice, — once in the fall of 1896, and once in the spring of 1897; and the levels over the portions which appeared to be most subject to change have been repeated several times, generally immediately after heavy storms, with a view to discovering, if practicable within a limited time, what changes were taking place in the contour of the harbor.

For the purpose of comparing the survey of 1857 with the surveys of 1876 and 1896, the plan of 1857 has been enlarged to a scale of 100 feet to an inch. While this plan may be taken as showing in a general way the conditions that existed in 1857, the lack of soundings or levels within the harbor makes it impossible to secure any definite comparison with the later plans by which the changes which have taken place could be definitely determined. The original of this plan was on a scale of $833\frac{1}{3}$ feet to an inch, and it has been necessary to enlarge it to more than eight times its original size, to compare it with the more recent plans; and, while the comparison indicates that considerable changes had taken place in the interval between 1857 and 1876 in the high and low water lines of the harbor, yet their amount cannot be definitely determined by means of this plan.

We find that between 1857 and 1876 the point of Duxbury Beach had apparently increased in height, which is indicated by the advance northward of the high and low water lines. In the same time Washburn's Point had grown toward the west into the channel of the harbor. In the upper part of the harbor just below the dike the plan of 1857 differs materially from that of 1876.

The plan of 1857 indicates that the greater portion of the bottom of the harbor inside the Narrows was below mean low water. At that time the channel passed from the vicinity of the place where the dike is now located along the south-westerly side of the large island, below which it widened out, narrowing again as it approached the Narrows, where its width at low water was about 125 feet. After it passed the Narrows it widened rapidly, until its width at the outer end was approximately 500 feet. Its width at high water in the Narrows was about 400 feet.

In 1876 the condition of the harbor between the vicinity of the dike and the lower end of the large island at low water appears to have been about the same as indicated by the plan of 1857. About one-third of the way between the lower end of the island and Washburn's Point the bottom of the harbor was, in 1876, exposed at low water, where the plan of 1857 would indicate that it was covered at all

stages of the tide. In 1876 the low-water channel passed out through the Narrows, where its width was 35 feet, and followed a course generally parallel to the northerly shore of the harbor at low water, its maximum width near its outer end being about 120 feet.

Upon comparing the plan of 1876 with the plan made in 1896 and 1897, we find that the point of Duxbury Beach has increased in height, and that the high-water line has advanced toward the Narrows. On the opposite side of the channel, also, it is found that Washburn's Point has advanced into the channel, the maximum advance at any place between 1876 and 1897 having been about 60 feet, and that the main channel of the river in the Narrows has been increased in width to about 55 feet between the low-water lines and reduced to about 140 feet between the high-water lines.

The other chief difference between the two plans is the elevation of the bottom of the harbor between the Narrows and the inner limit of the soundings of 1876, which is at the lower end of the large island; here we find that the greater portion of the bottom of the harbor is now more than 5 feet above mean low water, the highest point rising to nearly 8 feet above mean low water, whereas in 1876 the levels show that the bottom of the harbor was much lower. Inside Washburn's Point, between 1876 and 1897, there has accumulated about 75,000 cubic yards of sand within the area covered by the levels or soundings of the survey of 1876. In addition, it is evident that the bottom of the harbor is covered with a layer of sand considerably beyond the limit of the levels of the survey of 1876. At the present time the only considerable portion of the harbor that is below mean low water lies just below the dike, and extends from the dike, half-way between the outlet of the sluiceway and the northerly shore of the harbor, down to the upper end of the small island about 650 feet from the dike. Its total area is about 94,000 square feet, or $2\frac{1}{5}$ acres. The maximum depth of this area is about $6\frac{1}{2}$ feet below the level of mean low water; but the bottom of the harbor is so high along the south-westerly side of the large island that the water never flows out at the dike to a lower level than about $3\frac{1}{2}$ feet above mean low water. In the outer portion of the harbor, beyond the Narrows, a comparison of the two surveys shows very slight changes, and as nearly as can be estimated the bottom and sides of the harbor in this region have been filled to the extent of about 24,000 cubic yards.

From the pond just below the dike the low-water channel at the present time runs close along the south-westerly side of the large island and then along the easterly side of the harbor to just inside Washburn's Point, where it turns to the south-west, and then, turning again a right angle to the south-east, passes to low water about 500 feet south-west of Bluefish Rock.

In order to compare the depths of the channels, profiles have been made of the bottom of the channel, as shown by the soundings of 1876 and those of 1897. At the present time the bottom of the channel, beginning at the level of low water at a point about south of Bluefish Rock, gradually rises to about 1.2 feet above mean low water at a point 400 feet outside of Washburn's Point; thence it drops gradually until in the Narrows it is 2 feet below mean low water; thence it gradually rises again until at a point near the upper end of the larger island it is about 3 feet above mean low water, forming the overflow of the bar which holds the water in the pond just below the dike at a level about 3½ feet above mean low water, as already stated.

The changes in the elevation of the bed of this channel between 1876 and 1897 are substantially as follows: beginning at a point about south of Bluefish Rock, in 1897 the bottom of the channel was about .2 of a foot higher than in 1876; 400 feet inside of this, at what was the highest point outside the Narrows in 1876, in 1897 the bottom was about .8 of a foot higher; at the highest point of the 1897 channel, outside the Narrows, and about 400 feet therefrom, the bottom in 1897 was 2 feet above that of 1876; at a point about 100 feet outside of the Narrows, the bottom lines of the two channels are at the same level. At the Narrows the bottom of the 1897 channel is nearly 2 feet below that of 1876. Then they gradually come together and meet at about 300 feet inside the Narrows, and continue up the harbor substantially at the same elevation to what was the inner edge of the filling in 1876. The deepening in the Narrows between 1876 and 1897 was evidently caused by the current scouring the bottom to restore the area of cross-section which had been reduced in width by the building out of the points on either side, the material scoured out being deposited probably at either end of the Narrows.

At the present time the larger part of the tidal volume of the harbor is above the level of half tide, and the principal portion of the water is discharged during the first two hours of the ebb. At this time the tide is well up over the flat portion of Duxbury Beach, and the current is dispersed immediately upon passing the point of the beach. By the time the current is confined to the channel across the beach, there is a very small portion of the tidal volume remaining to be discharged. The shoaling of the channel outside the Narrows and the deepening which has taken place in the Narrows between 1876 and 1897, as described above, illustrates the effect of this dispersion of the first part, as well as the weakness of the latter portion of the ebb current. If the current had been confined to the low-water mark in the same way that it is confined opposite the point of the beach,

there would be undoubtedly a very good depth of water for the whole distance from the Narrows to the sea.

The channel of Cut River where it crosses the sand filling is constantly changing. It breaks its way through the point of Duxbury Beach to discharge into the main channel, and then gradually wears away its northerly bank and works itself up into the harbor. Then, generally in some storm, this channel is closed, and a new one breaks its way through the point of the beach. Four of these different locations are clearly shown on our plans.

During the time covered by our surveys, considerable quantities of sand appear to have been deposited on the marshes on the southwesterly side of the harbor between Cut River and the most southerly plank walk which runs over the marsh from Green Harbor Village to the harbor, and the sand in the harbor opposite this walk has a considerable growth of sedge upon it, the surface of the sand at this place being a little more than 7 feet above mean low water.

The outer slope of Duxbury Beach, extending for some distance southerly from its point, has worn away considerably since 1876, and it is probably from this source that a large part of the material for filling the harbor has come.

The heaviest storms we have on this coast are from the north-east, from which direction the wind has an unobstructed sweep directly from the ocean, and the waves created by these storms drive the sand and gravel along the beach in a southerly direction. Protected from the north-east, as the mouth of the harbor is, by Bluefish Rock and the headland of Branch's Island, which is protected by a natural riprap of boulders, it receives very little of its sand filling from these heavy storms; but, being wide open to the south and southeast, it is the natural receptacle for the sand stirred up by the lesser waves of the south-easterly storms, which, although less frequent, are still quite heavy, and it is undoubtedly by these waves, assisted by the flood tide, that the sand has been mainly carried into the harbor.

The surveys which we have made have covered a period of less than one year, and the changes have been so erratic that we have been unable to prove by definite measurements whether the sand filling is still increasing or not. On the whole, there appears to be a slight increase, but it is quite evident that the rate of increase is materially less than it was in the years immediately following the construction of the dike. The level at low tide of the surface of the water just below the dike, which is controlled mainly by the height and width of the bottom of the low-water channel, remains practically the same as it was when we began our measurements, in August, 1896. It varies slightly from day to day, the maximum range being about 0.5 of a foot.

This variation may be due partly to the amount of water being discharged through the dike, and partly to the length of time the surface of the sea is below it.

In considering the effect which the removal of the dike would have upon the harbor, we have obtained the following data from the results of our surveys and examinations. We have assumed that, if the dike be removed, the meadows above the railroad bridge will be protected by a dike at about that point, and that the dikes will be strengthened to keep the tide out of the cranberry bogs and ponds used for storing water for flowing the bogs which are situated on the southerly side of the meadows, and also that the small area north of the Neck Road, so called, would be diked off and so have not included them in our calculations. The last area is so small that, if it should not be protected, it would not materially affect the results of our calculations, which are necessarily somewhat approximate.

Assuming that, if the dike is removed, the water will rise over the meadows to the height to which it now rises in the river below the dike, the increase in the tidal volume of the harbor would be as follows: —

	Cubic Feet.
On a neap tide,	68,033,136
On an average tide,	132,292,840
On an extreme storm tide,	234,632,520

The tidal volume of the harbor at the present time between the dike and the narrows between Washburn's Point and the point of Duxbury Beach is as follows: —

	Cubic Feet.
On a neap tide,	10,040,000
On an average tide,	13,415,300
On an extreme storm tide,	49,311,000

The maximum ebb velocities through the Narrows at the point of Duxbury Beach range from about 3 feet per second at a neap tide to about 5 feet per second at an average tide, and to 6 or more feet per second at an extreme tide. These velocities at the present time maintain a cross-section of 750 to 850 square feet up to the level of mean high water at the narrowest place.

The maximum velocities occur, and the largest part of the tidal water enters and leaves the harbor, within two hours of high water, the bulk of the tidal volume of the harbor being above the level of half tide, and therefore is discharged early on the ebb. The volume discharged after half tide is so small that it affords very little power for scouring out the channel. To discharge the increased volume (amounting to eleven or twelve times the present tidal volume) which would flow in and out if the dike should be removed, without increasing

these maximum velocities, would require a cross-section extending from Washburn's Point to the marsh on the southerly side of the harbor, with its bottom 6 to 8 feet below mean low water. For a time, at least, the passage of this large volume would create very swift currents through the harbor, which would scour and enlarge a channel through the existing deposits. A portion of the material removed would undoubtedly be carried up into the river above the dike; but the larger portion would probably be carried out to sea and deposited in the vicinity of the present low-water mark, to be dispersed by the waves and the littoral currents along the shore, or driven back into the harbor entrance by the waves and flood current, to be again washed out by the ebb current. This enlarging process would be continued until the channel had been scoured to such an extent that the velocity of the current would be only sufficient to carry away the sand driven in by the sea and the wind. The tidal volume would, however, be much greater than in 1857, and consequently the channel would be likely to be considerably larger. Just what location and shape this channel would take through the beach cannot be predicted with certainty, but it is probable that in general it would be similar to the channel as it existed in 1857; and in order to secure the best results, a training wall of timber or stone should be built along the westerly side of the enlarged channel from the crest of Duxbury Beach to beyond the low-water mark, for the purpose of guiding the ebb current and depositing material as far out at sea as possible, and also for the purpose of obstructing the waves which dash on to Duxbury Beach, and of intercepting the heavy shingle which is now washed into the channel and across it on to the bank on its easterly side. It might also be necessary to do a certain amount of dredging and training inside the harbor to direct the ebb current, so that it would excavate a sufficient area for the anchorage of yachts and boats. The increase in this cross-section, if allowed to be formed by the current itself, would undoubtedly be largely made from Duxbury Beach on the westerly side of the outlet; as the bank on the easterly side of the outlet is composed principally of shingle with sand filling in the voids between the stones, while the point of Duxbury Beach is composed very largely of sand with only a comparatively small amount of shingle mixed through it. On the portion which would probably be washed away are located 25 houses.

Feasibility of improving the Harbor without the Removal of the Dike.

In investigating the subject of the removal of the dike, we have also taken occasion to inquire as to what might be done to improve

the present harbor, so as to form good accommodation for small yachts and fishing boats.

The general form and conditions which we naturally seek in a tidal harbor on a generally sandy coast line are one having a wide mouth, with its banks converging very gradually as they run inland, the banks inside the immediate sea-shore being composed of material not easily acted on by the tidal currents, with the estuary extending a long distance inland and having no enlarged basins except at considerable distances back from the sea, so that none of the sand from the shore can be carried into them. In a harbor of this description the tidal currents would be forced to follow the channel, and would ordinarily, when the tide is of considerable range, as at Green Harbor, be of sufficient force to scour out any sand or drift material which might be forced into its channel by the action of the sea. The other extreme would be a large basin just inside a sandy beach, or separated from the sea by a ridge of sand easily acted upon by the waves, the harbor being connected with the sea by a channel liable to be shifted with every storm, and through which large quantities of material would be forced by the waves of the sea and the flood current into the comparatively still waters of the pond, to be there deposited.

Green Harbor, in its condition previous to 1871, had many of the characteristics of the first form. Its mouth was protected from the heavy north-easterly gales by Bluefish Rock, and its tidal currents ran well up into the country and were discharged late on the ebb, when the water was confined to the channel through the beach, and was not dispersed at or near high-water level of the sea. In its present condition it is very much like the second form, being practically a pond immediately back of a sand ridge, which has already become largely filled with material driven in through the outlet through the beach, the greater portion of the tidal discharge occurring while the sea is near high water, and the small volume discharged toward low water being inadequate to maintain a navigable low-water channel through the beach.

From an examination of small harbors on the south shore of Cape Cod, where the rise and fall of the tide is only 3 to 4 feet or less, and where under natural conditions the entrance to the harbor will not float any boat larger than a light dory at any stage of the tide, it was found that vast improvements have been made, and entrances from 30 to 50 feet wide and 2 to 3 feet deep at mean low water created by simply building light timber jetties on either side of the entrance, thereby preventing the sea from driving the sand across the entrance and allowing the tidal currents to scour the channel. A small amount of excavating was also done to start the channel in its new location

between the jetties. At these places, in their natural condition, the tidal currents were so feeble that the sea drove the sand directly across the mouth of the entrance, leaving a very small outlet, which simply permitted the fresh water which came into the stream to flow out into the Sound. The water in front of these outlets is quite shallow and the waves cannot be very large and heavy, very much less than those which drive on to Duxbury Beach from the deep waters of Cape Cod Bay.

If jetties should be built at the mouth of Green Harbor to direct the current and prevent the waves from driving the sand and shingle into the channel, the results would probably be similar, — the depth of water at the entrance and in the vicinity of the jetties would be increased, but the main portion of the harbor inside the Narrows would remain practically in its present condition. The failure to remove the material within the harbor by the action of the current was illustrated at one of the small harbors on the southerly shore of Cape Cod, referred to above. At this place, where the storm waves broke down the jetties and drove the sand across the outlet, thereby nearly closing it, a portion was driven well up into the river, in very much the same manner as at Green Harbor. When the jetties were rebuilt, the sand between and near them was scoured out, but the portion farther inland remained.

In the case of Green Harbor, the bulk of sand and shingle which is now being forced into it by the waves could be intercepted by a jetty on the south-west side of the outlet, and only a comparatively small portion of the lighter material would be driven up over the jetty into the channel. A portion of this would be carried by the flood tide into the harbor and deposited there, and the other part would be carried out by the sea and deposited beyond the jetties, where it would probably be dispersed by the waves and littoral currents. The material now forming the bottom of the channel which would be enclosed by such jetty or jetties is composed largely of shingle, which would not be moved to any large extent by the current. The lighter portion would be washed away, leaving the heavier stone forming a riprap over the bottom. In order to create a sufficient depth of water, this would have to be removed by dredging or other artificial means.

In order to improve the conditions of the harbor itself, and make it a suitable harbor for yachts and boats, it would be necessary to excavate it by artificial means, as there are at present no sufficient volumes of tidal water which can in any way be directed to scour it out into the bay to any extent.

Some improvement might be made by utilizing the drainage from the water-shed of the river, which amounts on an average throughout

the year to about 1,000,000 cubic feet per day; but owing to the difference in the rate of flow of streams at different seasons, a quantity as great as 1,000,000 cubic feet per day would not be available in the summer season, while in the winter season the available flow would at times be very much greater. On the whole, it may be said that during the seven months from November to May inclusive it is probable that on an average a flow as great or greater than 1,000,000 cubic feet per day would be available; while in the months from June to October inclusive the flow might fall, in dry seasons, to 200,000 cubic feet per day, although in ordinary seasons a larger quantity would be available. By regulating the discharge of the water above the dike so as to have it all flow out through the dike during the last hour or two before the time of low water in the bay, it would materially increase the volume and velocity of the ebb current at the time when it should be doing its best work in scouring the channel, but at which time in the present condition of the harbor, the current has its least power. The effect of this would be felt in deepening and enlarging the low-water channel, especially on the crest of the sand dam, where the present channel flows out of the pond just below the dike. This could be augmented, especially during the drier months of the year, when the fresh water flow is small, in the following manner: if the dike should be made tight, an amount of tide water at least equal to the present leakage through the dam might be allowed to flow up through the sluices in the dam during each high tide, and be discharged again into the harbor just before low water, in connection with the discharge of the surface drainage. This could not create conditions any more objectionable than those due to the present leakage; but serious damage might be done by the admission of too great a quantity of sea water, unless care was taken in the operation of the gates; but the improvement created by this force would not, in all probability, be sufficient to greatly increase the value of the harbor, but as an element in maintaining the harbor after it had been otherwise improved it might be of more value.

The general scheme which suggests itself for the improvement of the harbor in its present condition without the removal of the dike would be to construct a jetty on the south-westerly side of the present channel, from a point on Duxbury Beach about opposite the most northerly and easterly cottage on the beach, running out substantially at right angles to the shore, to a point in the base line of the harbor survey, thence in a south-easterly direction, to deep water.

A smaller jetty might be needed on the north-easterly side of the channel, extending from the point of rocks west of Bluefish Rock south-easterly, substantially parallel with the main jetty. This might be a half-tide structure, its office being to direct the latter portion of

the ebb current directly on to the bar at the entrance, without seriously obstructing the entrance of the flood current. These structures should be built of rubble stone, and the main jetty should rise to above high-water mark, being slightly higher near the shore. Timber structures would accomplish the same object, but would probably last but a short time in this exposed locality (more especially the outer portions of them) ; and, from the experience which has been had with the small harbors previously referred to on the south shore of the Cape, if the jetties should give way the damage caused would be much more than the cost of rebuilding the jetties, as the sand would be driven into the channel, and it would undoubtedly have to be dredged and removed by artificial means to a considerable extent.

For the purpose of accommodating the yachts and boats which would be likely to use the harbor, it seems that a depth of at least 4 feet at mean low water should be provided. There is no volume of water available at present to create a current of sufficient velocity and volume to scour out any such depth, even with the help of the jetties, and therefore it would be necessary to excavate the channels by artificial means. After this is done, and the jetties constructed, we have reason to believe that, protected as the channel would be by the jetties, the available current would maintain it substantially as constructed, although it might possibly be necessary to extend the smaller jetty as a training wall farther in toward Washburn's Point, but this could be done at comparatively small expense. The rocks and other material near at hand would be available for doing a portion of this work.

The stream now known as Cut River, which comes from the creeks and marshes lying between the Rainbow bridge and the bridge from Green Harbor Village to the beach, flows into the harbor in such a way that it seriously obstructs its ebb current and decreases very materially its scouring effect.

If a training wall was constructed at the mouth of Cut River, to divert its ebb current and direct it out through the Narrows, it would accomplish a double benefit by turning what is now an injurious factor into a beneficial one.

The effect of Cut River on the flood current of the harbor is not injurious, but on the ebb current it is highly objectionable. It is partly due to this that the present channel is forced over on to the Brant Rock side of the harbor, and does not pass out as straight as it otherwise would through the Narrows at the point of Duxbury Beach.

Since 1871, as nearly as we can estimate it, the tidal volume of the basin has been reduced more than one-fifth by the sand being driven in from Duxbury Beach. This has been deposited principally below the level of half tide. If this sand could be removed, it would in-

crease the efficiency of the scour very materially and render more certain the maintenance of an improved channel. If only a portion of it should be removed, it would be of material benefit.

For the purpose of accommodating the boats which at present frequent the harbor, the excavation of an area about 300 feet square to a depth of 4 feet at mean low water would probably be ample. This could be extended from time to time, as the increase of the fleet demanded it.

The field work of the surveys and investigations at Green Harbor was in charge of H. V. DeHart from August to November, 1896, and of E. A. W. Hammatt from November, 1896, to June, 1897. Investigations as to the character of the soil, condition of the meadows, the flow of water in the stream and leakage through the dike were made by W. S. Johnson. Chemical analyses of soil and water, and investigations as to the effect of flooding the meadows with salt water, were made by H. W. Clark, chemist.

Respectfully submitted,

FRANK W. HODGDON,
X. H. GOODNOUGH,
Civil Engineers.

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Appendix No. 2.

State House, Boston, Dec. 8, 1897.

To H. P. Walcott, M.D., *Chairman of Joint Board on the Restoration of Green Harbor in the Town of Marshfield.*

Sir: — At the request of the Joint Board, I have made the following estimates of the cost of the necessary work and structures which would be required to carry out the different plans for the improvement of Green Harbor suggested in the report on that subject made to the Joint Board by Mr. Goodnough and myself.

1. Removal of the Dike.

An attempt to simply excavate and remove the material composing the dike to the depth of the original bottom of the river would be a very expensive operation. The upper portions would be very readily removed; but as soon as this was done, and the water allowed to flow in and out at each tide, the currents created would be so swift that it would be almost impossible to do the remaining work excepting during the very short time at slack water. This would take a very long time, and the liability of the machinery used to injury from the swift currents would be very great.

In order to avoid these difficulties, I have included in my estimates the cost of building and removing a temporary wooden pile and sod dam, to be erected across the river a short distance above the dike. This would enable the work of the removal of the dike and the construction of a pile bridge to carry the highway across the gap to be carried on in comparatively still water, and upon the completion of this work the temporary wooden dam could be readily removed.

The estimate for the removal of the dike for a length of 400 feet and to a depth of 4 feet at mean low water, together with the building across the gap of a bridge of oak piles with southern pine top and floor, and including the proposed temporary wooden dam, is as follows: —

Excavation (including removal of timber and piles), 17,200 cubic yards, at 75 cents,	$12,200 00
Temporary dam (including its removal),	6,000 00
For pile bridge to carry road across river, 8,000 square feet, at 75 cents,	6,000 00
Riprap abutments,	500 00
	$24,700 00
Plus 10 per cent.,	2,500 00
Total,	$27,200 00

For the purpose of securing the greatest improvement to the harbor by the above work, it may be found advisable to supplement it by the construction of a jetty on the south-west side of the outlet. If this is found to be necessary for the purpose of securing an increased depth of water over the bar, it would increase the cost of the work very materially, as a suitable jetty could not be built for less than forty thousand dollars.

2. Improving the Harbor without the Removal of the Dike.

For the purpose of improving the present harbor and making it accessible for yachts and fishing boats, it has been suggested that the harbor be improved by dredging an anchorage basin 300 feet square and 4 feet deep at mean low water, at some point inside of the Narrows at Washburn's Point, together with a channel of equal depth, 50 feet wide on the bottom, extending from the basin to the sea; the whole to be protected by a stone jetty extending from near the point of Duxbury Beach to deep water, its general direction to be substantially parallel with the present low-water channel, together with a smaller jetty extending in the same general direction from the northerly shore of the outlet just inside of Bluefish Rock. In addition to this, a stone training wall was planned to be built inside the harbor, to deflect and direct the currents at the mouth of Cut River, so that they shall not obstruct the current flowing from the main outlet. The estimate for this work is as follows: —

Stone jetties,	$35,000
Channel excavation,	10,800
Basin excavation,	10,000
Training wall,	5,000
	$60,800
Plus 10 per cent.,	6,080
Total,	$66,880

In making the above estimates I have adopted, wherever possible, prices at which similar work has been done in this vicinity under contracts with the general government, executed under the direction of the United States engineers. No plans have been made of the proposed work, but enough rough sketches have been drawn to give the necessary data for calculating the various quantities of material and labor required. I think the estimates have been made with sufficient care to warrant the belief that the work can be done for the amounts named, unless unusual difficulties are encountered.

Respectfully,

FRANK W. HODGDON,
Engineer, Harbor and Land Commission.

Appendix No. 3.

REPORT UPON ANALYSES OF SOILS FROM THE MARSHES AND DIKE LANDS OF MARSHFIELD, AND EXPERIMENTS UPON SECTIONS OF SOIL.

Laboratory State Board of Health, State House,
Boston, Sept. 14, 1897.

To H. P. Walcott, M.D., *Chairman of Joint Board on the Restoration of Green Harbor in the Town of Marshfield.*

Sir: — Herewith is submitted a report relative to the analyses of soils from Marshfield.

During March last an examination was made of 25 samples of material from the Green Harbor marsh and dike land. Fourteen of these samples were taken from 7 test pits above the dike, and 10 from 4 test pits below the dike. Simple inspection of the samples showed that all except those from pits Nos. 3 and 5 above the dike, and from pit No. 4 and the bottom of pit No. 3 below the dike, which were of a clayey nature, consisted of a black soil very full of roots, etc., and that the samples from one of these pits (pit No. 7) were really samples of peat. Many of the samples had an apparent specific gravity less than the specific gravity of water, largely due to the presence of so great a proportion of woody fibre in the samples.

During August an examination was made of 85 more samples, taken from test pits in the dike land and salt marsh. Sixty-six of these samples were from the land above the dike, and the remainder from the salt marsh below the dike. The percentage of water, by weight, held by these samples, was determined upon their arrival at the laboratory, and also the loss by weight of the dried sample when ignited to a red heat, until the organic matter present was burned off. The following figures give the number of each sample, the percentage of water held by it and its loss upon ignition: —

Number.	Water. Per Cent.	Loss upon Ignition. Per Cent.	Number.	Water. Per Cent.	Loss upon Ignition. Per Cent.
1,	35.24	12.90	42,	89.04	73.40
2,	35.05	4.66	43,	36.91	9.93
3,	62.34	22.90	44,	63.04	21.19
4,	72.19	28.31	45,	86.82	18.57
5,	60.59	15.32	46,	87.00	56.49
6,	79.18	36.95	47,	88.28	66.12
7,	82.22	41.02	48,	70.81	24.78
8,	86.02	51.90	49,	81.10	46.17
9,	87.60	74.25	50,	22.75	14.13
10,	33.94	14.89	51,	38.42	7.60
11,	45.92	13.62	52,	86.42	58.34
12,	84.53	50.70	53,	83.99	50.37
13,	78.72	35.61	54,	82.24	41.99
14,	42.64	17.45	55,	41.31	6.22
15,	64.73	61.67	56,	17.95	84.48
16,	73.69	37.26	57,	45.61	28.02
17,	86.76	57.84	58,	7.76	31.35
18,	54.41	35.17	59,	73.47	34.57
19,	82.39	54.23	60,	62.18	26.20
20,	80.98	56.93	61,	43.17	6.84
21,	13.60	3.73	62,	77.57	33.07
22,	80.91	61.45	63,	63.20	31.53
23,	42.03	25.78	64,	70.13	20.82
24,	59.62	13.07	65,	83.92	54.51
25,	54.55	4.19	66,	24.60	4.35
26,	78.00	37.66	67,	69.63	26.78
27,	72.85	25.83	70,	70.71	28.29
28,	67.11	30.65	71,	65.19	21.82
29,	82.35	60.66	72,	70.63	33.08
30,	28.21	5.08	73,	77.16	34.50
31,	80.85	55.75	74,	82.04	37.41
32,	86.92	56.46	75,	84.68	60.40
33,	90.31	83.28	76,	85.53	18.06
34,	82.47	91.41	77,	72.09	24.75
35,	89.00	94.58	78,	57.37	1.00
36,	83.20	84.10	79,	70.39	25.86
37,	90.82	79.89	80,	71.00	49.00
38,	88.72	75.60	81,	86.24	75.71
38A,	85.85	84.72	82,	90.16	74.59
39,	87.18	65.46	83,	86.36	63.29
40,	89.00	69.53	84,	89.04	64.82
41,	88.84	88.04	85,	89.23	64.15

Samples numbered from 1 to 65 inclusive were taken from the lands above the dike.

It will be seen from these figures that nearly all of these samples lost a very large proportion of their weight upon ignition. This loss is on account of the fact that there is a very large amount of roots and woody fibre in the samples. These roots were, in almost every sample taken above the dike, much discolored and decomposed; in

the samples taken below the dike, on the other hand, the roots and woody fibres were bright, and clearly in a state of vigorous life and growth. No chemical tests will show the difference between the samples so well as simple inspection.

EXPERIMENTS WITH CYLINDERS OF SOIL TAKEN FROM THE DIKE LANDS.

During the last week in July, a section of soil, 20 inches in diameter and 2½ feet in depth, was taken in an iron cylinder from the southerly portion of the dike lands and sent to the Lawrence Experiment Station for experiments with regard to the effect upon this soil of repeated flooding with salt water and draining. The upper 6 or 8 inches of this section, that is, the surface soil at this place, lost upon ignition 16.03 per cent. by weight, and had an apparent specific gravity of 1.07; the next foot of material lost upon ignition 66.95 per cent., and had an apparent specific gravity of .89; the lower foot lost upon ignition 45.33 per cent. by weight, and had an apparent specific gravity of .94.

The section of soil was of such proportion that it fitted loosely within the galvanized-iron cylinder. Upon arrival at the Experiment Station the bottom of the cylinder was perforated in several places, and also the sides of the cylinder near the bottom. The cylinder was then placed within a wooden hogshead. Salt water was allowed to run into this hogshead slowly, entering the iron cylinder at the bottom, and rising around and through the soil until the surface was covered. This flooding took about six hours. The surface remained covered for an hour, and then the water was slowly drained from the cylinder. This was repeated each day for two weeks. Across the top of the wooden hogshead a cleat was nailed, and from four points upon this cleat measurements of its distance from the surface of the soil were made twice each day, once when the cylinder was flooded and once after draining. This experiment was continued for two weeks, with hardly a perceptible result upon increasing size of the cylinder of soil, the greatest variation shown by any of the measurements being $\frac{1}{16}$ of an inch.

Finally, the cylinder was allowed to remain covered with water for several days, and as a result of this its surface became covered with a very rank, mouldy growth; and when the water was withdrawn and the soil drained, decomposition of the roots and other organic matter was so active that it resulted in giving a very strong and offensive odor to the soil.

Upon August 17, a similar experiment was begun with another section of soil of the same size, from a different portion of the dike land. This second section was taken from a place where it seemed

probable that flooding with water would cause an expansion of the soil, if any of the dike soil could be so affected. The upper 6 or 8 inches of this section of soil had an apparent specific gravity of .69, and lost upon ignition 62.72 per cent. by weight; the foot beneath this upper portion had an apparent specific gravity of .78, and lost upon ignition 58.51 per cent.; the lowest foot had a specific gravity of .70, and lost upon ignition 50.79 per cent. by weight. This soil was flooded for two weeks, as above described, and upon each flooding the surface was raised approximately 2 inches and lowered again when the water was drawn from the cylinder. This rise of the surface upon flooding was not caused by the floating of the soil, as was proved by observation when the cylinder was intact, and also by taking large pieces of the soil and immersing them in water. They invariably, when saturated with water, would sink; but when dry, or nearly so, would float upon the water. After this flooding for two weeks, this sample of soil was treated in the same manner as the first section, by allowing it to remain covered with water for about two weeks, when, as with the first section, a vigorous growth of moulds appeared upon its surface, and portions of the soil taken from the cylinder had a very strong and offensive odor. After this treatment the cylinder was again flooded each day, and this flooding is being continued at the present time.

Respectfully submitted,

H. W. CLARK,
Chemist.